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MEDICAL EDUCATION

MEDICAL education continues to be the subject of very lively discussion. In 1944 the Good-enough Committee issued its much-quoted report on the "Organisation of Medical Schools"[1]. A year ago an authoritative sequel appeared in the form of the General Medical Council's "Recommendations as to the Medical Curriculum"[2]. Newer and detailed proposals have now been published under the title "The Training of a Doctor" under the authorship of a Curriculum Committee that was set up in 1945 by the British Medical Association[3]. In the background, reaching far back over the years, are many other reports on the same subject. Before considering where the British Medical Association's proposals stand in relation to those of the Goodenough Committee and the General Medical Council, it is useful to consider for a moment why the medical curriculum is always under fire. For so it would seem to be if one compares medical with other university departments; there has certainly been no corresponding wealth of reports about the teaching of chemistry, physics or electrical engineering.

The underlying reason would seem to emerge from the fact that the medical sciences, which are part of the general field of biology, have not evolved very far in the hierarchy of science. The physical sciences are well to the fore, and in their present state of development conform far more closely to the pattern that is expected of a well-knit and properly based structure of scientific knowledge. This in turn allows a clear academic separation between the fundamental sciences of physics and chemistry and such applied subjects as mechanical and chemical engineering. Corresponding divisions of interest are quite impracticable on the biological side. As a result, to take an example, the student of zoology or of agriculture may find himself equally concerned either with fundamental or applied science. The same dual, and at times confused, purpose besets the medical departments of a university. Thus, the overwhelming task of a medical school is to train practising doctors. Its next task, but a task not second in importance, is the training of medical scientists and the advancement of medical knowledge. It is this division of purpose which is clearly the background for all educational difficulties in medicine.

Because the two objectives of a medical school are pursued in the same harness, the curriculum for 'applied medicine', if it can so be called, is always immediately affected by changes in fundamental medical knowledge. Unfortunately, however, the curriculum has never been automatically readjusted so that proper weight is given to new advances in relation to old-established knowledge. What has generally happened is that new subjects, as they grow in importance, have been added to the existing syllabus, the structure of which has thus been altered not by changes in its general configuration, but mainly by the process of discrete accretion. Not surprisingly, the medical course has in consequence increased over the past thirty years or so from four to six years. If the same

process were to continue, and the strong claims of new interests were admitted, there is no saying how many years would have to be allowed for the training of a doctor in twenty years time.

Here lies the main driving force behind the constant stream of discussions about the reform of the medical curriculum. There is a second to which the British Medical Association Curriculum Committee directs attention—namely, that advances in medical knowledge over the past fifty years have not resulted in a "proportionate improvement" in the standard of medical practice. It is almost a truism that the practice of medicine is more up to date in relation to new biological knowledge than are most industrial and engineering undertakings in relation to advances in the physical sciences. But this is obviously no reason for complacency, and the British Medical Association is right in insisting that, without improvements in the system of education, little can be expected in the quality of our medical graduates. Allowing for the fact that the bulk of the sixty thousand medical men in Britain are in one or other kind of practice, and therefore circumscribed in the expenditure of their energies, it is a startling fact that over the past fifty years or so, most major and fundamental advances in medical science have come from the few hundreds who have kept to the research laboratory. This is all too painfully obvious when one scans the list of Nobel laureates in medicine, or lists of medically qualified men who have been elected to the Royal Society—or to corresponding bodies in other countries. One cannot suppose that more than a fraction of the best minds among medical graduates have dedicated themselves to the laboratory. It is tragic, therefore, to contemplate how circumstances and education have limited the potentialities for advancing medical knowledge which actual practice provides.

In the remedies it suggests, the British Medical Association is at one with the Goodenough Committee and the General Medical Council about such things as the need to eliminate unnecessary detail and specialities from the curriculum; about the desirability of 'integrating' its various parts; and about the fact that the time is ripe to introduce into the curriculum such subjects as psychology and social medicine. It takes an independent line about many matters of more detailed policy. For example, it opposes the Goodenough recommendation that chemistry, physics and general biology for intending medical students could be taught in schools; it holds that anatomy and physiology could be confined to four instead of the five terms recommended in previous reports—although in this recommendation, since its proposed terms are longer, all that is suggested is the curtailment of vacations; it disagrees with the Goodenough Committee that, in general, one can combine good teaching and research abilities in the same individual, and suggests that where the head of a department is a research man, someone else should be made responsible for the teaching.

These and other like matters are, however, questions of detail. The real point is whether the British Medical Association's proposals regarding the direction and integration of the curriculum will achieve the "aim of the medical curriculum". The report takes the line that "the undergraduate medical course should be primarily concerned with the training in those basic principles of medicine which are a necessary foundation for all forms of medical practice". This in turn implies that the student should be trained over the whole field of medicine. "There should be no clash in outlook", the report reads, "between the practitioner and the research worker", since both use the same intellectual methods. And the British Medical Association Committee holds that a proper medical education would have the effect that the medical practitioner would continue to be a student throughout his postgraduate career.

Specialization in education is repeatedly attacked, and the report pleads for what is described as the "synoptic view". It argues for a "liberal and general" school education for intending medical students, and opposes early "vocational" concentration on science; "general culture", it states, should take the place of "premature narrow specialization in the basic sciences". In its insistence on the need for 'integration', it points out that the many subjects which come into the medical curriculum break the continuity of the student's career. For example, physics, chemistry, and biology should be taught in the first year of the medical course "as different aspects of general science". From this would emerge an understanding of the general principles of scientific method, which would be further laid bare in the syllabuses for anatomy and physiology. Continuity would be better assured by such measures as distributing the teaching of pathology and psychiatry throughout the clinical years, and integration would be helped by ceasing to break up the final examinations into the separate disciplines of surgery, medicine, gynæcology, and so on. The emphasis throughout the report is on re-ordering the curriculum to the end that the patient be seen as a whole. General medicine, the Curriculum Committee claims, is the 'linchpin' of the clinical subjects, and should be taught as the basic clinical subject from which the specialities have branched. "It must remain an integral study of human disease in all its facets, both physical and mental."

A number of these proposals are undoubtedly very sound. But on the other hand, the value of the report is not strengthened by obscure concepts, and in particular by what seems to be an undue allegiance to words such as 'unity', 'whole', 'fundamental principles' and 'general culture'. A synoptic view is clearly useful; but its over-emphasis seems to detract from rather than to enhance its importance. Man, we are told, must be regarded as a whole, and not as the sum of his component systems; "the sense of the unity of medicine is the special purpose of the teaching of general medicine". Instead of emphasizing excessive morphological detail, "the general truths of anatomy" should be inculcated. Students, we are also told, "must not be allowed to think that laboratory investigations are a substitute for personal observation. They should be trained to understand that the purpose of X-rays, pathological reports, and the like, is

to refute or confirm the practitioner's own findings, and that they must be regarded as servants, not as masters."

It is difficult to avoid feeling that these are mostly platitudes. It is undoubtedly true that a man with a general education is often more interesting and intellectually alert than one without. But as a class, are doctors any less 'cultured' than, say, an equivalent number of men who did not concentrate on science in school and the university? It is obvious also that a doctor should regard his patient as a whole, and "not as a collection of systems and organs corresponding to the specialities of medicine". But when a patient comes to a doctor, is he really regarded as such? It is perfectly true, too, that a man should not become the victim of the techniques of observation which he uses. But equally, is it correct to imply that pathological studies or X-ray methods are not just another form of personal observation?

Above all, it is dangerous to obscure the fact, which is what the Report does, that advances in medical knowledge have come about almost entirely out of increasing specialization, and through the fragmentation of the 'oneness' of medicine. The 'general physician' may be a disappearing species, but it has disappeared over a period in which the health of the people has been progressively improving.

How a deliberate avoidance of educational specialization, beginning at school and continuing through to the end of the 'intern' year spent after medical qualification, can materially improve the quality of medical practice is, therefore, difficult to see. More, not less, specialized scientific training would seem to be wanted if full advantage is to be taken in practice of advances in fundamental medical science. One wonders, therefore, whether the British Medical Association is not attempting the impossible, in so far as the verbal character it imposes on medical education is out of keeping with the trend of developments in medical practice. More and more the general practitioner is taking on the function of a sorting-machine which directs those sick whom it cannot help into specialized avenues for particular treatments. This fact the British Medical Association report clearly recognizes; but nevertheless it consistently seems to write down the importance of the specialities. The trend cannot be condemned because specialization can be carried too far. That danger will be there whatever form medical education takes. Nor can the trend be stopped, for the simple reason that advances in knowledge, not only in medicine but also in every other field of science or applied science, inevitably mean greater and greater specialization.

If medical education is to undergo the fundamental overhaul which the British Medical Association Committee rightly describes as necessary, it is surely essential to safeguard the education of the specialist, and the specialist approach, as well as that of the general practitioner. The problem is whether the two aims can be satisfied by the same curriculum. The period of medical training is already very long in relation to the years of a doctor's service, and if several more years have to be added to a general medical curriculum for gaining experience in a speciality, the burden of education becomes almost too great. Sooner or later the question will have to be faced whether the approach to reform should not be the opposite of that advocated in most recent reports, including that of the British Medical Association Committee. What may be wanted is the division of the curriculum into specialized 'sectors' that cut right through the clinical and pre-clinical subjects. In such a vertical organisation, the cardiovascular 'sector' or 'department', or the neurological 'department', or the infectious diseases 'department', would embrace their relevant anatomical, physiological, pathological and clinical aspects. The medical student, after an initial year or so in which he became familiar with the language of the subject, and, in general terms, the layout of the body and the nature of its mechanisms, as well as the broad character of the most frequently used techniques of medical education and practice, could move from sector to sector, becoming educated in all aspects of each in the integrated way demanded by the British Medical Association Committee. Teachers would be sufficiently experienced to indicate the interrelations of different sectors, and so to impress the 'wholeness' of medicine in its most useful sense. The time spent in different sectors, and the emphasis of instruction in each, would be varied according to the needs of general practice. But no more time would be spent in all than would be deemed necessary to train a man for the declared purposes of general practice. After his first qualification, the would-be specialist would then concentrate in the sector or sectors of his interest, in an atmosphere where basic science and applied knowledge form an interrelated pattern, and in which either one or the other could become the central interest. A synoptic view over the whole field of medicine seems impossible to attain. A synoptic view within a sector of, say, the problems of digestion and nutrition—all the way from their anatomical to their biochemical aspects—or of the locomotor system, is far more within the bounds of educational possibility. In short, horizontal may have to give way to vertical integration if the medical curriculum is to be materially improved. At the moment the preclinical subjects of anatomy, physiology, and biochemistry supply the normal picture of the whole field that is later split up into the variety of specialities that make up clinical medicine. No amount of horizontal integration or of reference back during the clinical years to the preclinical subjects is likely to achieve as useful an interrelated pattern of education as would a vertical division of interests.

It is in these major matters that the British Medical Association report is least convincing. On the other hand, it contains many useful suggestions that could be immediately applied in medical schools, to the betterment of present educational methods. Very useful, too, is its suggestion that there be formed an "Association of Teachers in Medical Schools" to discuss alternative possibilities for the curriculum—for the British Medical Association Committee has wisely recognized that all proposals are in the nature

of plans for experimental action, and that plans must necessarily change with the changing content of medicine itself.

[1] Report of the Interdepartmental Committee on Medical Schools. (H.M. Stationery Office, 1944.) (Reviewed in *Nature*, **154**, 322; 1944.)

[2] Recommendations as to the Medical Curriculum. General Medical Council, April 1947. (Reviewed in *Nature*, **160**, 481; 1947.)

[3] The Training of a Doctor. Report of the Medical Curriculum Committee of the British Medical Association. (London, Butterworth and Co., Ltd., 1948.) 7*s*. 6*d*. net.

FERN PHYLOGENY

Genera Filicum

The Genera of Ferns. By Dr. Edwin Bingham Copeland. (Annales Cryptogamici et Phytopathologici, Vol. 5.) Pp. xvi + 247 + 10 plates. (Waltham, Mass.: Chronica Botanica Co.; London: Wm. Dawson and Sons, Ltd., 1947.) 6 dollars.

A Revised Classification of Leptosporangiate Ferns

By E. E. Holttum, *J. Linn. Soc. London*, **53**, pp. 123–158 (1947).

BY a curious coincidence two independently compiled reclassifications of the ferns have appeared in print almost simultaneously but from different parts of the world. Both are of very considerable botanical interest, since the phylogeny of ferns is a topic of wider evolutionary significance than the taxonomic context alone might suggest. The phyletic views of the late Prof. F. O. Bower, based largely on anatomical and developmental data, are well known to all morphologists and have for long been the basis of teaching in many universities. The phyletic views of the pure systematist in pteridology have, however, been only imperfectly available. Christensen's phyletic scheme published in 1938 was regarded by its author as only tentative, though unfortunately he did not live to develop it more fully. This scheme has, however, been kept vividly in mind by both the authors under review and both can, in a sense, be read as commentaries on Christensen as on Bower.

The circumstances of composition of the two works are very different. Holttum's explanation of his own is that it was a sequel to the compilation of a Fern Flora of the Malay Peninsula which had been carried out at Singapore between 1942 and 1944, that is, during the Japanese occupation. The step from this to a reclassification of the leptosporangiate ferns seems, therefore, to have been in a sense unpremeditated and the outcome of close acquaintance with the very rich fern vegetation of that country. By being confined to a limited section of the ferns the ground covered is that contained in vol. 3 of Bower's classic work, all of which was, until quite recently, included in the spacious but unnatural family, the Polypodiaceæ.

In Holttum's view the Polypodiaceæ *sens. lat.* should be replaced by five families, namely, Polypodiaceæ *sens. strict.* (including *Polypodium* and *Dipteris*), Grammitidaceæ, Thelypteridaceæ, Dennstædtiaceæ and Adiantaceæ.

To a British botanist the chief interest of these innovations is likely to lie in the third and fourth families. By placing the male fern (*Dryopteris Filix-mas*) as a derivative of *Dennstædtia*, Holttum departs from, and perhaps undermines, one of the central tenets of Bower's phylogeny by which the Dryopteroids are thought to derive from an ancestor with superficial but not marginal sori. Further, by separating the marsh fern (*Thelypteris*) not merely into a different genus from the male fern but also into a different family, the Thelypteridaceæ, Holttum endorses and extends a long-considered view of Christensen's that the genus *Dryopteris sens. lat.* is polyphyletic. With this latter view, it may be said in passing, some recent cytological work of the reviewer is in complete agreement. An independent statement of somewhat similar views had previously been published by Ching[1], though this could not have been known to Holttum at the time.

Copeland's book is a work of greater scope, since it sums up the views of a life-time primarily devoted to the study of ferns and is intended as an authoritative work of reference, an intention which is on the whole excellently fulfilled. It includes the whole of the ferns and is preceded by a few pages of highly instructive historical introduction in which the taxonomic views and practice of the author are briefly discussed. Of the 305 genera recognized and described, only six have not been personally accessible to him, while 33 have been created by him and 69 others revived. Some familiar genera have, on the other hand, been suppressed, and a British botanist will perhaps be surprised to note the submergence of, for example, *Scolopendrium* in *Asplenium*. The treatment of the Polypodiaceæ (which is split into twelve families) differs in many ways from that of Holttum—a divergence which is easily understandable in the light of Copeland's introduction; but both authors endorse the views of Christensen in his treatment of *Dryopteris* and in other ways. Of the new or revived genera a large proportion occur in the Hymenophyllaceæ, the 600-odd species of which are distributed into thirty-three genera instead of the two unwieldy groups of *Trichomanes* and *Hymenophyllum*. Pedantic as this may at first appear it is clearly an essential preliminary to the attainment of clarity on phyletic trends within this large and interesting group.

The weakest part of the book is the treatment of anatomy. This is clearly not the centre of the author's interest, though he is compelled to make some use of it in his treatment of the Polypodiaceæ. It is perhaps scarcely his fault that comparisons with Bower will be more consciously made by some of his readers than they may have been by himself; but the extreme compression of the allusions to anatomy makes their inclusion of doubtful value in certain cases. The very well known and complex stem structure of the bracken (*Pteridium*), for example, is merely referred to as a solenostele without further qualification—a degree of simplification which amounts almost to distortion.

On the positive side, a point of unusual interest to a northern reader is the stress which is laid on the southern hemisphere as the putative place of origin for a large proportion of existing fern genera. This view had been strongly impressed on the author by his earlier studies of the Hymenophyllaceæ and other groups, which still have a predominantly southern distribution, and also by his long residence in the Philippines and familiarity with their flora. According to Copeland nine-tenths of all tropical fern genera are of southern origin, and that the Antarctic continent itself may have been the centre of this evolutionary development is an idea which is less familiar to northern botanists than its importance deserves. For this reason alone the book deserves close and critical study by students of vegetation as well as by students of ferns. It should also perhaps be mentioned that the potential value to pollen analysts

of the numerous descriptions of fern spores has already been pointed out by Erdtman in a Swedish review; the absence of illustrations may, however, perhaps prove a disadvantage here.

Though it is always possible, in a compilation of this kind, to make suggestions of detailed improvements, these should not, in this case, be regarded as seriously detracting from the sterling value of this book, which as a taxonomic study will remain an indispensable source of reference for many years. Not only the author, but also the publishers are to be congratulated on the production of a compact, convenient, and scholarly piece of work.

I. MANTON

[1] Ching, C., "Natural Classification of the family Polypodiaceæ", *Sunyatsenia*, 5, pp. 201–267 (1940).

PATHOLOGY OF TUMOURS

Pathology of Tumours

By Prof. R. A. Willis. Pp. xxiii + 992 + 52. (London: Butterworth and Co. (Publishers), Ltd., 1948.) 63*s*. net.

IN all branches of biology where the experimental method, and the co-operation of the chemist and the physicist, are extending our knowledge of living things, it is still essential for the results of morphological inquiry not only to be preserved but also to be reviewed, summarized and restated in the light of contemporary opinions. The descriptive morphologist acquires his knowledge and judgment by long experience, which no interloper, however gifted with modern techniques, can hope to achieve in a short space of time as a subsidiary interest. This is particularly the case with microscopical work, where sound interpretation of the visual image usually requires long experience and training.

Nevertheless, the chemist and physicist who are partners in a modern biological research team will seek at least some acquaintance with the morphological side of the problems they are investigating, and here is a book on tumours which not only pathologists but also all workers in cancer research will find extremely valuable. The author has not provided just another detailed work of reference, confined to the systematic description of the structure of tumours. He begins with an admirable summary, extending over twelve chapters, of the main characteristics of tumour formation, their mode of origin, statistical study of incidence, experimental production in animals, metastases, and the theories of the nature of neoplasia. The second part of the book describes with commendable precision the characteristic features of tumours in specific regions of the human body and includes many case-histories, together with information on comparable tumours in animals.

It is now generally accepted that the successful production of an advanced text-book should be the work of collaborators each responsible for some particular section. So many text-books by a single author are apt to become reproductions in condensed form of the existing literature, enlightened only in those sections where the author has detailed experience. Dr. Willis makes it quite clear that, though he wishes to give a general outline, much of the book is a personal record of his own observations and conclusions. The five hundred illustrations are all from material he has studied personally. Inevitably there are controversies concerning the interpretation of some types of tumour. Where conflict arises with other pathologists, it is refreshing to find the author stating his convictions, avoiding 'non-committal vagueness' and at the same time admitting that his own opinions may have to be modified in the light of further research. There is a vigour and a challenging frankness in his criticism of the work and opinions of others which is perhaps characteristic of the Australian temperament. Where controversies have been tediously prolonged, the more heretical contributors are singled out as "pathologically incorrigible, absurd or deservedly moribund"—expressions which English authors of scientific books and papers unfortunately go out of their way to avoid. The author's opinions, though forcibly stated, are given, however, with reasons that can only be helpful in allowing the reader to distinguish reasonable hypothesis from dogmatic assumption.

As a work of reference the book is well constructed with clear headings to the numerous sub-sections of each chapter. In the references the more important papers are distinguished by a full title with the author's name in block capitals, while the less important papers are indicated in smaller type without title. Dr. Willis wrote this book while holding the Sir William H. Collins chair of comparative pathology in the Royal College of Surgeons of England. He is now director of the Department of Pathology of the Royal Cancer Hospital, London.

E. S. HORNING

FORCES BETWEEN COLLOIDAL PARTICLES

Theory of the Stability of Lyophobic Colloids

The Interaction of Sol Particles having an Electric Double Layer. By E. J. W. Verwey and J. Th. G. Overbeek, with the collaboration of K. van Nes. Pp. xi + 205. (New York and Amsterdam: Elsevier Publishing Co., Inc.; London: Cleaver-Hume Press, Ltd., 1948.) 22*s*. 6*d*. net.

MANY of the classical investigations of colloidal chemistry were concerned with the stability of colloidal solutions of insoluble substances, such as gold, arsenic sulphide, silver halides, etc. The well-known phenomenon of coagulation of these sols by comparatively small concentrations of electrolytes suggested that their stability was connected with their electric charges. A considerable amount of research has been made in the past to discover the magnitude and origin of the electric charge on the particles and the nature of the electrical double layer which exists around them in salt solutions. Although qualitative and semi-quantitative explanations have been given of the phenomenon of coagulation and of the rule of Hardy and Schulze, according to which the ionic concentration required for precipitation diminishes rapidly with the charge of the effective ion, yet a complete and satisfactory theory was still lacking.

The present volume contains the results of theoretical investigations on the problem which were carried out by the authors in the Netherlands during the war years. Some short and incomplete accounts of this work have appeared in various journals, but many of the details are published here for the first time. The book, therefore, has the character of a research monograph. It undoubtedly takes the problem to a

more definitive stage and will be studied with care by all who are interested in electrical double layers and with the colloidal state. The publishers are to be commended for making the work available to the English-speaking world in such a complete form.

Briefly, the authors' object was to examine in detail the potential curves for the interaction of particles which are obtained by combining the repulsion which arises from the interaction of their double layers with the London – van der Waals' attraction. Following preliminary work by J. H. de Boer and H. C. Hamaker, it is found that a fairly complete explanation of the coagulation process is obtained from the consideration of the combination of these two types of interaction, using reasonable values of the London attractive constant.

For many readers the most interesting part of the book will be the discussion of long-range attractive forces between particles, which are large compared with atomic dimensions. It is found by summation between all the atoms that the van der Waals' attraction diminishes comparatively slowly over distances comparable with the particle size. As this would give rise to appreciable forces between large particles, a relativity correction is suggested to the London expression, which has the effect of reducing to zero the van der Waals' forces at distances of more than about 10^{-6} cm.

One consequence of the slow decline of the van der Waals' attraction within this range is the fact that at the greater distances the attractive forces may again exceed the repulsive, giving a shallow minimum in the potential energy curves at distances of the order of 10^{-6} cm. It is suggested that this may produce thixotropy with non-spherical particles and may be responsible for the curious phenomenon observed by Bernal and Fankuchen with tobacco mosaic virus, namely, the concentrated aqueous phase in which the rod-shaped protein molecules are arranged in alignment at distances varying from zero to 300 A. or more.

J. A. V. Butler

CORROSION OF METALS

An Introduction to Metallic Corrosion

By Dr. Ulick R. Evans. Pp. xxxvi + 211. (London: Edward Arnold and Co., 1948.) 12*s*. 6*d*. net.

THE author's object in writing this book was, in his own words, "to provide an account of Corrosion short enough to be read from start to finish within a reasonable time". Let it be said at once that he has succeeded in his purpose and succeeded admirably. This "Introduction to Metallic Corrosion" provides a general, authoritative and up-to-date survey of the subject, which the serious student should be able to master in the course of a few weeks.

The format and general lay-out of the book resemble that of Dr. Evans' "Metallic Corrosion, Passivity and Protection", but the text is much shorter, amounting roughly to one quarter of that of the major work. This compression has been achieved by the elimination of a considerable amount of less important detail and the rearrangement of the subject-matter in eight chapters as compared with fourteen. The chapter headings provide an apt summary of the contents and illustrate the simple logical classification adopted by the author: they are: film growth; electrochemical corrosion; corrosion by acids and alkalis; influence of environment; effect of stress, strain and structure; prevention of corrosion by soluble inhibitors; prevention of corrosion by protective coverings; and statistical and mathematical treatment. The same methodical arrangement is followed in the sub-headings. For example, those for Chapter 6, "Prevention of Corrosion by Soluble Inhibitors", are: principles of inhibition; cathodic inhibitors; anodic inhibitors; inhibitive water treatment in industry; pickling processes to remove scale and rust; inhibitive pretreatment.

All this renders the book easy to read and to follow. It will also be evident from these headings that, while Dr. Evans dwells with unequalled authority on the whole range of corrosion theory, he is at pains to deal with the practical aspects of the problem and to render the utmost assistance to those who have to grapple with corrosion in the rough and tumble of industry.

One attractive and likable feature of the book is that references to the literature are reduced to a minimum; even so, 165 are needed. These are segregated at the end instead of being given as footnotes. Too much attention can never be paid in any scientific text-book to details such as this, which, however unimportant in themselves, in the aggregate make all the difference between a readable and a tedious book. As an eminent psychologist has written, "It requires considerable effort even to follow one's inclinations with consistency", and any aids such as this to lighten the burden of study are not to be despised.

The book is prefaced by an excellent historical introduction. In this, Dr. Evans covers attractively, in the short compass of some five thousand words, the development of knowledge of the subject from the dawn of history to the present day. Some of the theories, held even by research workers who are still alive, make rather queer reading now; but the general impression gained from Dr. Evans' survey is that of constant progress resulting from the integration and interplay of the ideas of a large number of earnest seekers after truth. Not all of them have been cast in an academic mould, for as Dr. Evans remarks: "Industrial necessity has led to the investigation of many points which the pure scientist would probably have overlooked".

He gives an example to illustrate this. An even better one might be that intuitive reasoning alone could scarcely disclose that the initial cause of the corrosion of steel railway sleepers is damage to the protective tar coating caused by the hob-nailed boots of the men walking up and down the line!

The only feature of the book about which a little diffidence might be expressed is the final chapter on statistical and mathematical treatment. It might have been better to omit this. Statistics is a highly specialized subject, to which Dr. Evans has made important contributions, and it is no aspersion on the mental calibre of many who read this book to suggest that they will find this chapter difficult. Dr. Evans has evidently considered this point and was, no doubt, influenced in his decision by the fact that the subject-matter had not previously been published as a connected whole.

In brief, this is an attractive, well-written and well-produced book which will fulfil the purpose for which it is intended, and will undoubtedly appeal to a much wider circle of readers than the more comprehensive "Metallic Corrosion, Passivity and Protection". It is fully worthy of the author's high reputation.

J. C. Hudson

THE ATOMIC ENERGY RESEARCH ESTABLISHMENT, HARWELL

THE Atomic Energy Research Establishment was founded by a decision of the Government in November, 1945, and Prof. J. D. (now Sir John) Cockcroft was appointed director in January, 1946. In order to provide a nucleus of accommodation and a prepared site, the permanent R.A.F. aerodrome of Harwell was allocated to the Establishment and building work began there in April, 1946. Harwell was chosen because of its convenient geographical location, combining reasonable access to London with nearness to a large university (Oxford), which was considered to be important so that staff should have good opportunities for discussion with university colleagues.

A nucleus of experienced staff was available in 1946, some of whom had worked in the United States Atomic Energy Project at Los Alamos and Berkeley, while others had helped to build the Atomic Energy Plant at Chalk River in Canada. These were joined by experimental electronics staff working at the Telecommunications Research Establishment in Malvern, and by a few senior members of universities. This nucleus has been added to by the recruitment of junior staff, and there are at present Divisions of Theoretical Physics, Nuclear Physics, General Physics, Chemistry, Chemical Engineering, Metallurgy, and Health, each of the size of a large university research school.

The Establishment has very close links with the universities and industry. Many senior members of the project after the War returned to take charge of university departments; these scientific workers are now consultants to Harwell and some of them serve on the Technical Committee which advises the Department of Atomic Energy. In addition, many of the technological problems of the Establishment are solved by collaboration with industry and with laboratories of Government departments and research associations.

The purpose of the Establishment is to carry out fundamental research and development in atomic energy. It is responsible also for providing scientific and technical information to the Controller of Production, Atomic Energy (Lord Portal) and his engineering organisation at Risley, which is preparing the design for the plutonium production plant which is being built near Sellafield in Cumberland.

Pile Programme

The first requirement for an atomic energy programme of this nature was to build piles, and the first pile, GLEEP (graphite low energy experimental pile), was completed in August, 1947. It is a slow neutron graphite moderated reactor developing 100 kW. of nuclear energy. The simplest possible design was chosen so that early experience could be gained in pile operation, and, in fact, the time taken from beginning constructional work to the start-up of the pile was only just over a year.

It has a concrete shield, five feet thick, and the graphite blocks and natural uranium rods are built up within the shield roughly in the form of a cylinder lying on its side. The power-level at which the pile is operating is measured by means of boron trifluoride chambers sunk into the pile, and the current in the chambers suitably amplified is displayed in the control room on a dial calibrated directly in kilowatts. This information is also used to maintain the power of the pile at a constant level by controlling the position of neutron-absorbing cadmium 'control rods', hanging vertically in the pile. A second set of 'shut-off rods' is available to shut down the pile.

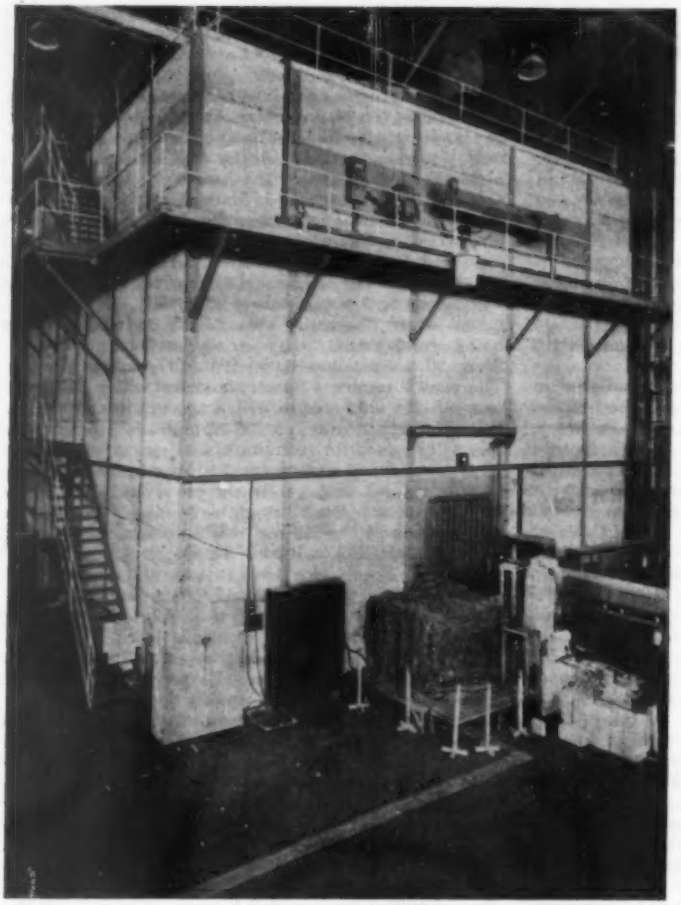
GLEEP is being used for measurement of the properties of atomic nuclei, for testing the nuclear properties of materials used in the construction of piles and for the production of radioactive isotopes.

The second pile, BEPO (British experimental pile), started up at 3 p.m. on July 3, 1948. Although not much larger physically than GLEEP, it is a much more complicated engineering structure and is designed to develop 6,000 kW. of nuclear energy. The heat is removed by an airstream which is drawn through the channels in which the uranium rods lie, and exhausted through a 200-ft. chimney stack. This pile will be used for studying the effects of irradiation on the structural and physical properties of materials which will be used in future piles, and the much higher neutron flux available makes possible a correspondingly wider range of experiments than in GLEEP. BEPO will also be the main source of radioactive isotopes for Great Britain, and it is expected that this work will be transferred from GLEEP to BEPO towards the end of this year, thus freeing GLEEP for full-time experimental work.

In preparation for building these two piles, it has been necessary to develop the production of pure graphite both in Canada and in Great Britain, and also to produce pure uranium metal and fabricate from it the aluminium-encased uranium rods which are used in the piles. This work has involved a large development programme, all of which has been undertaken outside the Establishment, both by industry and other Government establishments.

After the operation of piles, the next stage in a pile programme is the extraction of plutonium from the irradiated uranium metal, and information on the extraction process will be required for the Sellafield plant. The chemical problems involved in the separation of plutonium from the unused uranium and the highly radioactive fission products are among the most difficult in the atomic energy programme, and for this and other radiochemical work a new laboratory is being built at Harwell. This new radiochemical laboratory is a large two-story building, consisting of a central administrative block, connected by air locks and changing rooms to two wings. The wings contain a number of self-contained laboratory suites, each fitted with lead-lined chambers where all radioactive work will be done. A very large air flow is required through the chambers, equivalent at maximum rate to 120 air changes per minute in the laboratories, and this has led to the provision of an exceptionally large ventilation system, the air ducts for which, together with other services, occupy the whole upper floor of the building. Until this building is complete, temporary laboratories for the work have been provided in one of the original buildings.

Buildings are also being erected for chemical engineers, who will follow up the work of the research chemists with semi-scale plant. The chemical engineering programme includes the study of methods of extraction of uranium from the many kinds of low-grade ores in which it occurs.



General view of GLEEP

Industrial Applications of Nuclear Power

The Atomic Energy Research Establishment is working on the problem of the application of nuclear power to industrial purposes. A very small beginning will be to extract from the cooling air stream some of the heat developed by BEPO and to use it for space heating. A heat exchanger for this purpose is being installed.

The design of natural uranium piles in which power could be generated as a by-product at a moderate efficiency is being investigated in detail. This investigation is not complete; but it would appear that the construction of such piles is likely to be technically feasible. They would not, however, be worth while economically since such piles only burn up a very small proportion of the uranium. They would only be worth while as a first step to gain experience.

If nuclear power is to become important in the world, four major problems have to be solved. First, the so-called breeding problem must be solved—uranium 235, the only naturally occurring, or 'primary', nuclear fuel must be made to breed 'secondary' fuel from more abundant materials: either plutonium from uranium 238 or U233 from thorium. Second, materials must be found which will stand high temperatures and be suitable for use in pile construction. Third, the chemical extraction problem must be solved—the fissile material produced must be separated economically from the unused uranium or thorium and the intensely radioactive fission products. Fourth, a method of disposal must be found for the large amount of unwanted radioactive material which would be produced by power stations operating on nuclear fuel.

These problems are difficult, and their solution is going to take time. For this reason, no serious person working in the field believes that nuclear energy will make any contribution to world power during the next decade. At present, work is entirely in the theoretical and laboratory stages; but it is probable that a number of pilot plants will be built to allow all these problems to be investigated. Until this is done no accurate assessment of the possibilities for the future can be made.

Nuclear Physics

For fundamental research in nuclear physics the Establishment is being equipped, in addition to the two piles, with several particle-accelerating machines.

A frequency-modulated cyclotron with 110-in. diameter pole pieces is under construction which will produce particles with a maximum energy of about 200 MeV.: it will be completed about the end of this year. This machine will enable the nuclei of most atoms to be broken up, and will be used to produce new types of nuclei which cannot be produced in the piles.

For the production of monokinetic beams of lower-energy particles, a 5-million volt Van de Graaff generator has been built. The design is similar to that of a machine recently completed by Prof. Van de Graaff at the Massachusetts Institute of Technology, and close contact has been maintained between the Atomic Energy Research Establishment and the Massachusetts Institute of Technology teams. The design voltage has been obtained without the accelerating tube in position, and tests are in progress with accelerating tubes. A 2-MV. machine for work in radiation chemistry has been built and is being tested by the manufacturer.

In addition to machines for work at Harwell, the Establishment is assisting universities and the Medical Research Council by carrying out, on behalf of the Department of Scientific and Industrial Research, development of high-energy particle accelerators for use in universities and medical departments. A group working at the Telecommunications Research Establishment in Malvern is directing the

development of synchrotrons, including two 30-MeV. machines for the Medical Research Council, a 140-MeV. machine for the University of Oxford and a 300-MeV. machine for the University of Glasgow. It is also developing the design of linear accelerators and recently completed a 4-MeV. machine which is now in great demand for experimental work in nuclear physics and radiation chemistry.

Apart from accelerating machines, a beta spectrometer has been completed with provision for automatic recording, and small groups are working on the design of neutron spectrometers and other problems.

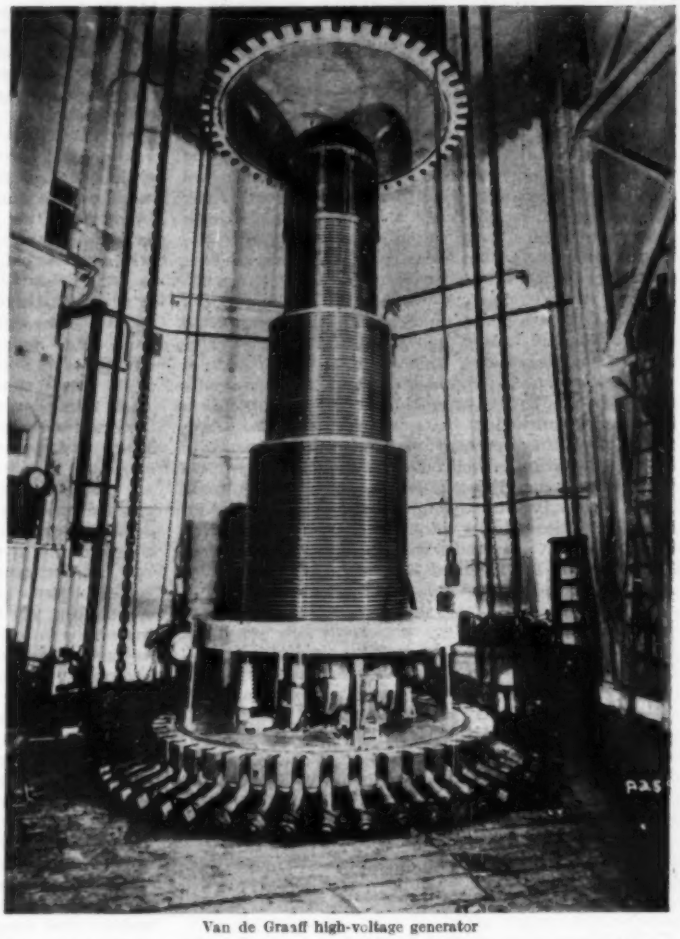
The Isotope Programme

It has already been announced that GLEEP has been used for the production of radioactive isotopes since September 1947. The rate of production of samples has increased steadily and is now about 150 per month. Altogether more than eight hundred deliveries have been made, mostly to English universities and hospitals and to workers at the Establishment, but including a few to European countries, and one air delivery to South Africa.

It is expected that BEPO will take over the production of radio-isotopes towards the end of 1948. It will then be the main source of radio-isotopes for Great Britain, and will make it possible to extend the supply to countries in the British Commonwealth and Europe. The higher neutron flux available will allow the preparation of a much wider range of materials, and of higher activity samples.

It is intended that the chemical processing and delivery of samples, except those with very short half-lives, will be undertaken by the Radio-Chemical Centre at Amersham, and arrangements have been made for the Chemical Research Laboratory to prepare complicated organic molecules containing radio-carbon, when these are required.

In addition to radio-isotopes, the Establishment will produce separated stable isotopes of many elements. Research groups are working on the separation of stable isotopes by several methods, including thermal diffusion, fractional distillation and chemical exchange. A thermal diffusion plant for the preparation of enriched oxygen 18 is being built, which should give by autumn 1948 a yield of 1/7 gm. of oxygen 18 per week, at a concentration of 20 per cent. A 34-ft. fractional distillation column, working with liquid carbon monoxide, will be complete in a few months time, and should give a yield of 0·3 gm./day of carbon 13 by the end of the year. A small-scale electro-magnetic separator has been built for other elements, and a much larger instrument, capable of separating any elements, is being erected. Several mass spectrometers are available for assaying samples, and some development work on the design of these instruments is being undertaken.



Van de Graaff high-voltage generator

Electronics

An atomic energy project requires a great variety of electronic instruments, for example, for pile control, radiochemistry, experiments in nuclear physics and health monitoring. A considerable section of the staff is engaged in designing and developing these instruments. In general, the design is carried to a stage where it can be taken over for production by industry, and the Establishment takes the initiative in finding the requirements of university and medical users, so that their needs also can be met in both the design and production stages.

Health

In view of the possible hazards from radiation and radioactive dusts, very stringent precautions are taken at the Establishment, and the health of all workers is the responsibility of a Medical Division. Everybody is given a thorough medical examination on joining the Establishment, and this is repeated

periodically. Workers exposed to radiation have their blood examined from time to time to see whether any change occurs in the number of cells, due to exposure to radiation. Safety measures taken have been such, however, that no over-exposure has occurred and there has been no single case of any harmful effects due to radiation.

Arrangements for the monitoring of scientific workers and their laboratories for radioactivity are the responsibility of a Health Physics Group. Staff exposed to radiation carry a photographic film to record the total dosage taken each week, and those working in very active areas carry pocket condenser chambers from which they can see at any time the amount of radiation to which they have been exposed since the chamber was charged. In addition, fixed instruments are placed in the pile buildings, active chemistry laboratories and grounds to provide a continuous record of radiation. Portable instruments are used to make measurements during any operation such as withdrawing materials from a pile. As a result of all these precautions the actual exposure of staff to radiation is well below the levels which have been recommended by the Medical Research Council. The Health Physics Group is also responsible for monitoring the effluent water from the Establishment and seeing that it complies with the rigid specifications laid down by the Medical Research Council.

SOME NEW RHEOLOGICAL PHENOMENA AND THEIR SIGNIFICANCE FOR THE CONSTITUTION OF MATERIALS

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AND
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THE materials studied in rheology are of varied constitution, with intricate patterns of constituent components of visible, colloidal, molecular, atomic and sub-atomic sizes. The patterns range from a *coarse-grained* type in which a discontinuous structure is apparent, to a *fine-grained* one which appears homogeneous and continuous to the eye and even to the microscope; the former type is represented by biological tissues, textile materials, natural and synthetic sponges, foams, powders, timber, cement, etc., and the latter by gases, amorphous liquids and solids, single crystals, etc. In the engineering constructions of Nature and man, widespread use is made of coarse- and fine-grained materials, and this invites an investigation into their mechanical properties as exhibited in changes of volume and form, and into the relation between these properties and the constitution of the materials.

In the present article we shall discuss experiments in which we use both types of material, the coarse-grained ones being particularly valuable here because they can be made to give combinations of mechanical properties suited to the purpose in hand and not easily available in the fine-grained types. Moreover, one can easily vary the constitution of a coarse-grained material by physical means and observe macroscopically how the mechanical properties depend on the constitution. As an example, consider coarse-grained sponges of rubber or rubber-like substances. The sponges can be made to display large elastic recoveries of strains for changes of both volume and form, a combination not found in fine-grained materials. Moreover, the sponges can be made in various structural designs, including the extremes of an *open* structure with intercommunicating holes, and a *closed* one with isolated holes, and also covering a wide range of mixed structures in which the holes may be filled with air or viscous or visco-elastic liquids. Another example is provided by the coarse-grained assemblies of fibres, ranging from single hairs to textile fabrics, and yet another by powders, etc. We select from the materials of all types samples of a size sufficiently large to allow a determination of the mechanical properties in terms of a *continuum theory*, the coarse- and fine-grained structures alike being averaged out into continua over regions of macroscopic, microscopic or submicroscopic dimensions. For the coarse-grained materials we can then observe simultaneously the mechanical properties as defined by the continuum theory, and the constitution as revealed by the structural pattern of the components of macroscopic size, and thus have a means of correlating one with the other. For the fine-grained materials we can observe the mechanical properties as before, and elucidate by analogy the correlation with the hidden constitution on a microscopic and submicroscopic scale.

For ease of reference we shall introduce a nomenclature suited to distinguish between different kinds of response to mechanical actions. We have examined all the materials first in their natural state, when they are at rest and free from externally applied forces, and we use the term 'isotropic' to indicate that the material in its natural state displays full spherical symmetry in response to actions along the various directions in space; the term 'compressible' is used to indicate appreciable changes in volume within the range of actions considered; and the term 'shear elastic' to denote in that range an appreciable amount of shear strain recovery under a sudden release of all external forces. By contrast, we use the term 'anisotropic' for a deviation from spherical symmetry, and the terms 'incompressible' and 'shear inelastic' when the changes of volume and of shear strain recovery respectively are inappreciably small.

Continuum Theory of the Elasticity of Volume and Form

In the discussion of a continuum theory of the elasticity of volume and form, we shall restrict ourselves to materials which are isotropic in their natural state, since the theory appears for these materials in its simplest form.

We consider here a differentially small portion of an elastic material. Under an applied load of external forces, the portion will pass from its natural state to some static state of equilibrium, shortly referred to as the 'loaded state', and will appear there as a cube with edges of unit length. In transit from the natural state the cube will have acquired in the loaded state a certain *strain*, according to the changes in volume and form, and a certain *stress*, according to the

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external forces which appear here as traction forces per unit area acting across the faces of the cube. We can then resolve the strain and the stress into components tangential and normal to three adjacent faces of the cube, arrange these components into two square matrices, and define quantities, termed scalar invariants, which remain unaltered under all changes of orientation of the edges and faces of the cube to which the matrices refer. For a given matrix one can express any arbitrarily considered scalar invariant as a function of three, and only three, mutually independent ones, which are distinguished as the first, second and third in accordance with their degrees in the matrix components, and defined respectively as the sum of the terms in the principal diagonal, the sum of the minors of these terms, and the determinant of the matrix. It is then the task of a continuum theory of elasticity to introduce the laws which relate the matrices of stress and strain to one another.

The classical continuum theory considers only infinitesimally small strains, and assumes for these the validity of Hooke's law. When we apply this law to isotropic materials, we find that the changes of volume must be independent of the tangential components of stress, and the changes of form must be independent of the normal components. Moreover, the law postulates here that the changes of volume are linearly proportional to the mean *isotropic pressure*, calculated as the arithmetical mean of the normal components of stress, and the changes of form linearly proportional to the *deviatory stress*, calculated by subtracting the mean isotropic pressure from the total stress present; the proportionality factors are known as elasticity moduli of volume and of form respectively.

The general continuum theory[2] by contrast considers strains of any amount, small or large, and makes no assumption as to the validity of Hooke's law. We find then for isotropic materials that the changes of volume and of form become interdependent in the sense that the tangential components of stress make some contribution to the changes of volume, and the normal components of stress make a contribution to the changes of form. Lord Kelvin[3] foreshadowed such a possibility in the following words: "It is possible that a shearing stress may produce, in a truly isotropic solid, condensation or dilatation in proportion to the square of its value". We find a general law, according to which the changes in volume can always be expressed as a function of the three scalar invariants of the matrix which represents the stress. It will be noted that the first invariant of stress is linear, contains only the normal components of stress, and is equal to an isotropic pressure multiplied by the factor three, while the second and third invariants are of degrees higher than one and contain normal and tangential components. For a first-order approximation, such as may be allowed for infinitesimally small strain, we neglect terms of higher degrees in the stress components and so find in accordance with Hooke's law that the changes in volume will depend only on the isotropic pressure. When, however, the strains are of appreciable amount, we must take terms of all degrees into account, and we then find non-Hookean terms in the changes of volume which make these changes disproportional to the isotropic pressure, and dependent on both the shear and normal components of stress. In particular, it is to be expected that under large amounts of strain changes of volume may occur even though the first invariant of stress, and the isotropic pressure, are equal to zero, and further, that even paradoxical effects may be expected in which, for example, the volume is decreased while the isotropic pressure acting across the face of a differential cube is a pull. Such a paradox is resolved when one regards the three different invariants as a result of three different ways of forming mean values by averaging over the full solid angle of directions in space. The first invariant corresponds to a mean of the first powers, that is, to a simple arithmetical mean, while the second and third invariants correspond to means of second and third degrees respectively. In the Hookean postulate it is assumed that, for changes of volume, only the arithmetical mean of the traction forces is of importance, while in the general theory means of higher degrees are also admitted.

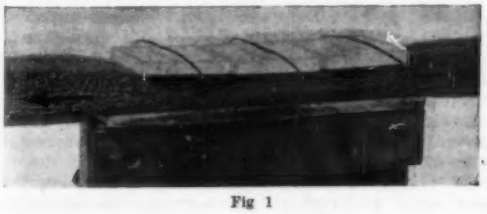
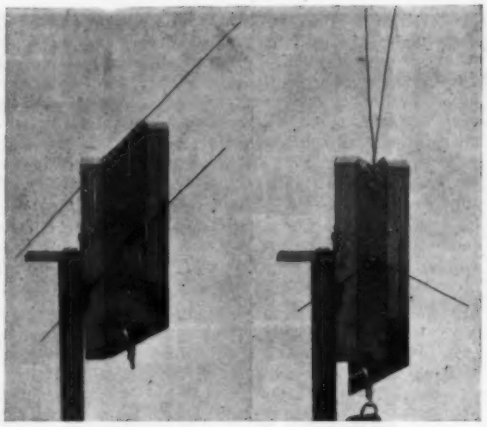


Fig 1



(*a*) (*b*)

Fig. 2

To demonstrate experimentally the whole range of effects which are expected in accordance with the general laws we need isotropic materials capable of large elastic recoveries of strain, both in volume and in form. Such materials are available only in a coarse-grained type, and are here provided by the air-filled sponges of rubber with open and closed structures. These sponges show in a striking manner the non-Hookean terms in the changes of volume.

Fig. 1 refers to a sample of sponge rubber which is pulled lengthwise by a 7-lb. weight (indicated by arrows) and simultaneously compressed in height by three blocks of 'Perspex', each loaded by a pair of ½-lb. weights. Attention should be focused on that part of the rubber sponge which lies beneath the middle block, since the blocks on either side are used only as guards intended to secure a nearer approach to homogeneity in the middle. A measurement of the dimensions of the sample reveals that the volume

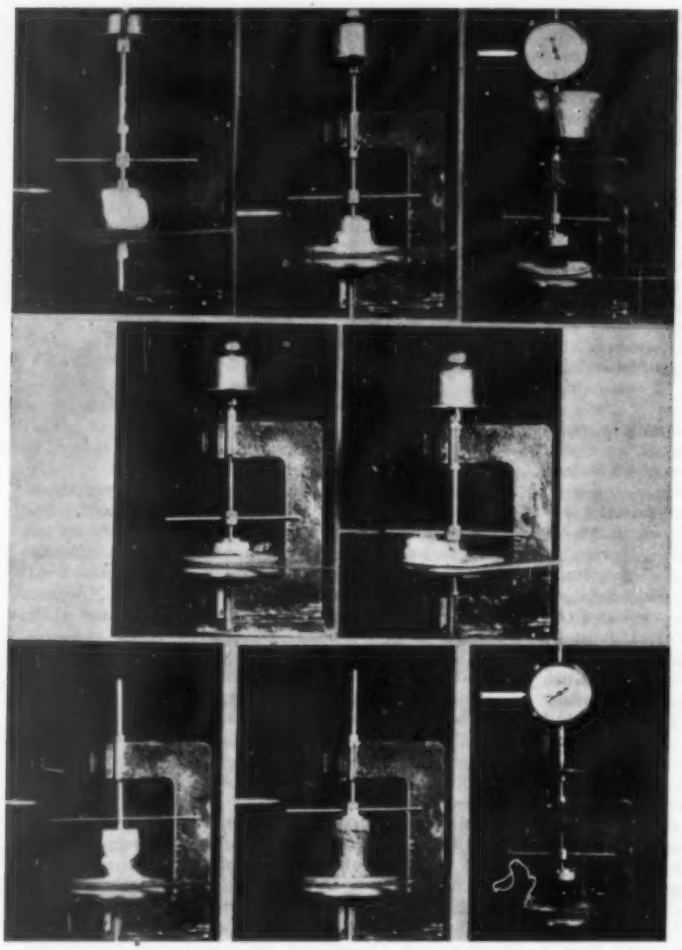


Fig. 3

of the middle part is reduced by about 40 per cent compared with the unstrained state, as the conspicuous decrease in height completely overshadows the changes in the dimensions in length and width. At the same time, the mean isotropic pressure is distinctly in the sense of a pull, since per unit area the lengthwise pulling force is about twenty times as great as the vertical compressive force.

Fig. 2 (*a*) and (*b*) refers to an open sponge rubber cemented between two blocks of wood, the unstrained state being shown on the left (*a*), while on the right (*b*) is the strained state reached when a weight is hung on a bracket fixed to one of the wood blocks. It can be seen that in the strained state the sponge has contracted in all three dimensions, the ends and sides being sucked in, as revealed by the motions of the attached wires, and the thickness being reduced as shown by the decrease in the distance between the wood blocks. In this experiment volume reductions exceeding 40 per cent have been noted, while an examination of the stresses (which is difficult on account of the fact that the stress is heterogeneously distributed in the sponge) shows a mean isotropic pressure in the sense of a pull.

Similar results have been obtained in experiments on samples of sponge rubber of the closed type, and this means that the volume effects shown in Figs. 1 and 2 are by no means restricted to materials with structures in which the changes of volume can occur through an expulsion of the air from the holes in the structure.

Constitution of Matter

In flow experiments on coarse-grained materials, one may observe on a macroscopic scale both the structure and the particular kind of mechanical behaviour displayed, and then correlate one with the other. Such a correlation is difficult to establish for fine-grained materials, since the structure cannot be observed macroscopically. If, however, similarities in behaviour are found between two materials, one visibly discontinuous and the other apparently continuous, the structure which is seen in one provides a possible model (at least) for that which is unseen in the other. (Such an idea appears frequently in scientific literature. H. Mark and F. Eirich used suspensions of elongated particles in liquids to simulate colloidal solution of long-chain molecules, and Sir Lawrence Bragg used groups of soap bubbles to throw light on the sub-visible details of the crystalline structure of metals.) In this way a bridge can be built between the structural and the continuum theories, and an approach made towards finding for the fine-grained materials a correlation between structure and the rheological behaviour.

Preliminary experiments were made to reveal the correspondence in rheological behaviour for the various types of materials here considered.

We first tested the shear elasticity by applying a shearaing ction and observing the recovery of shear strain under a sudden release of all external forces, so distinguishing between shear-inelastic and shear-elastic materials. We thus collected into the shear-inelastic class some types of fine- and some of coarse-grained materials, the former including optically clear brittle solids, Newtonian liquids, and gases, and the latter dry powders such as chalk, glass, etc. Similarly, we were able to group into the shear-elastic class certain fine-grained types, including colloidal solutions of gelatine, cellulose, rubber, saponified oils, etc., and certain coarse-grained types including the rubber sponges (open and closed) and a large variety of assemblies of fibrous constituents, with the fibres occurring as single hairs or yarns, curled up or stretched out, arranged in a random or orderly manner, varying in length from a millimetre to several metres and composed of wool, cotton, rayon, silk, metal, asbestos, etc.

We then tested the compressibility of the materials and drew a dividing line between the materials

termed incompressible and those termed compressible. To a first approximation the dividing line can be drawn so that we find on the side of the incompressible materials fine- and coarse-grained types which are wholly in the condensed states, that is, solid, liquid or intermediate, while on the side of the compressible materials we find the types which are wholly or partly in gaseous states. The division is particularly interesting for the shear-elastic class, in which we find that the types of fine-grained materials considered, namely, the colloidal solutions, are wholly condensed and thus incompressible, whereas the coarse-grained types of rubber sponges and fibrous assemblies contain gases (air) and are accordingly compressible.

On the basis of the classification given above, we can predict in a qualitative way the behaviour under various conditions of the materials within one class and division. We shall illustrate these predictions by describing for the coarse- and the fine-grained materials of the same class experiments under conditions chosen first so that all the materials behave alike because of their class resemblance in shear elasticity[1,2], and secondly, so that they behave differently on account of the additional complications caused by the differences in compressibility.

In the experiments illustrated in Fig. 3, an upright cylindrical specimen of the material considered was subjected to torsion between two parallel disks, the lower one fixed in height but capable of rotation, and the upper one free to move up and down but prevented from rotating. This was achieved by mounting the lower disk on top of a pulley, and securing the upper disk to a stem which slides in a sleeve and carries a crossbar which is checked by the supporting frame. The cylindrical wall of the specimen was left open to the atmosphere. Experiments were performed with various materials including liquids, fibrous assemblies and rubber sponges, but only the shear-elastic materials are shown since the others produce effects of a merely trivial kind. To apply the torsion it is necessary that the material should stick to the disk. For the liquid no special measures are required, but for the fibres it is necessary to face the disks with glass paper, and the sponges must be secured by cementing (thanks are due to Messrs. Dunlop Rubber Co., Expanded Rubber Co., and B.B. Chemical Co., who supplied us with a wide range of sponges, expanded rubbers and adhesives). The photographs show the results of the application of torsion. The pointer on the left-hand side of a picture indicates the original height of the top disk by pointing to the original position either of the crossbar, or of the hand of the dial-gauge.

The first row shows three pictures referring respectively to a fine-grained material, namely, a colloidal solution, and to two coarse-grained materials, namely, a fibrous assembly and a sponge with a closed structure. The materials are subjected to torsion while at the same time they are compressed by a weight. Under these conditions the materials develop stresses which drive them inwards to such an extent as to push the top disk upwards against the action of the weight. The amount by which the top disk rises differs in the three cases, being greatest for the colloidal solution, less for the fibrous assembly and so small for the sponge as to require a dial gauge to reveal it. For the colloidal solution, the torsional motion has to be maintained at constant velocity during the exposure, as otherwise the liquid would lose its stress and run out of the gap. (It is particularly striking that the stresses hold this material in place despite the opposing influence of gravitational and centrifugal forces.) On the other hand, the sponge is a solid which is subjected to a static torsion. The fibrous assembly can be treated as a solid or a liquid, and the torsion applied statically or dynamically.

The second row of pictures shows a visco-elastic liquid and a fibrous assembly. The arrangements are similar to those used for the previous experiments, except that now the speeds and other conditions of the experiment are so chosen that a disturbance occurs in the form of an eddy which rolls the material up and then ejects it from the gap. The photographs were taken at the instant of ejection. No exact theory has yet been developed to account fully for this phenomenon, which occurs exceptionally in liquids but commonly in the fibrous assemblies; it was first observed by K. Weissenberg and R. J. Russell on some specially prepared visco-elastic liquids.

All the photographs so far discussed show the similarity between the coarse- and fine-grained materials. By contrast, the third row shows the additional complication produced in the coarse-grained materials because of their compressibility. The specimens are a fibrous assembly, an open sponge and a closed sponge, in all cases cemented to the disk and treated as solids. A statical torsion has been applied; but in this case without weighing down the top plate. All the materials are again drawn inwards, but the upper disk is pulled down, that is, in the opposite sense to that shown before. It is evident that the materials have been reduced in volume by the waisting and reduction in height.

From the experimental observations cited, it may be concluded that a wide range of structures of cellular or fibrous type provide possible models for the hidden molecular structure of the apparently continuous colloidal solutions in the shear-elastic class. Such models would be insufficiently resistant to changes in volume, and it would be necessary to provide for the missing resistance by appropriate assumptions.

Thanks are due to the director of the Shirley Institute for giving us the opportunity to carry out this work and permission to publish it. We are indebted to Mr. C. Bradley and Miss J. Gallagher for the photographs accompanying this article.

[1] Freeman, S. M., and Weissenberg, K., *Nature*, **161**, 324 (1948).
[2] Thomson, Sir W., "Math. and Phys. Papers", III, XCII, Part 1, 34.
[3] Weissenberg, K., *Nature*, **159**, 310 (1947).

BRITISH ASSOCIATION

BRIGHTON MEETING

THE programme for the 110th Annual Meeting of the British Association for the Advancement of Science has now been published. The meeting will be held in Brighton during September 8–15, under the presidency of Sir Henry Tizard, who will deliver an address on "The Passing World" in which he will review some of the outstanding features of the progress of science and technology in Great Britain from the close of a period of stagnation towards the end of the nineteenth century.

The meeting will be held, as usual, in thirteen concurrent sections with a number of joint sessions, and the programme also includes evening discourses and a session of the Division for Social and Inter-

national Relations of Science, at which Dr. Julian Huxley and others from Unesco will discuss "Science Across the Frontiers".

The sectional programmes contain a wide variety of topics, ranging from cosmic magnetism to the effects of the cinema on young people. The objects of the annual meetings of the Association being to provide opportunities for men of science to meet each other and discuss their work in the setting of science as a whole, to allow men of science and laymen to meet each other, and to increase the public understanding of science, the programme includes both specialist and general topics (nearly three hundred speakers).

Among the former are sessions on recent advances in the crystalline state, opened by Sir Lawrence Bragg, geology and air photography, functional morphology (including an address by Prof. H. Graham Cannon), the denudation of the weald, applicable mathematics, the case for and against the metric system, transmission of effects from the endings of nerve fibres (opened by Sir Henry Dale), recent advances in colour vision (including an address by Prof. H. Hartridge), to mention only a few.

The more general topics include industrial applications of electronic devices (with exhibition), new metals in industry, new building materials, problems of Colonial development, movements of population, fuel economy with special reference to the heat pump, human blood groups, problems of old age. Various aspects of food and nutrition will be discussed at several sessions arranged by the Sections of Zoology, Economics, Physiology, Agriculture and Chemistry, and the programme also includes discussions and talks on science in industry as arranged by no fewer than seven sections.

Arrangements have been made for sixty excursions and a number of social engagements, and the members will be entertained at a civic reception in the buildings on the Royal Pavilion Estate.

Further details of the meeting may be obtained from the Secretary of the British Association, Burlington House, London, W.1 (Regent 2019). There is no closing date for registration, and hotel accommodation is still available in Brighton.

THE SWEDISH DEEP-SEA EXPEDITION

By Prof. HANS PETTERSSON
Göteborg

An account has already been given of the first part of the cruise of the *Albatross* (see *Nature*, October 25, 1947, p. 559). On August 27, 1947, the *Albatross* started from Balboa on its cruise across the Pacific Ocean, and five months later terminated it in the idyllic harbour of Ternate, visited by the *Challenger* Expedition seventy-three years earlier. The course led first to the Galapagos Islands, where the upwelling cold water and the deposits beneath it were studied; then along a west-north-west direction until the eighteenth parallel was reached, from there turning south for Nukuhiva and for Tahiti. Between Tapeete and Honolulu the course of the *Challenger* was followed, although to the opposite direction, several of its stations being repeated under way. From Honolulu the course lay to the south-south-west and, after crossing the equator for a fourth time, we steered west-north-west, finally reaching the great deeps south-east of Mindanao.

Our four first crossings of the counter-equatorial current were used for a close study of its hydrography by frequent deep series, intercalated by bathythermograph shots through the uppermost 140 metres. Interesting results are shown by our diagrams, as the signs of upwelling and descending water in the regions of divergence and convergence respectively in the surface. A distinct oxygen minimum extended from a few hundred metres downwards for 800 m. or more. Clouds of suspended particles studied by the Tyndall method were met with also at great depths.

The ruggedness of the sea bottom revealed by our echograms often proved an obstacle to coring operations, as were also the not infrequent encounters with hard bottom (lava beds) at great depths, sometimes leading to partial or total loss of the steel coring tubes. Nevertheless, fifty-seven cores, varying in length from a few metres to fifteen metres, were raised from depths between 2,000 and nearly 8,060 m., their total length approaching 500 metres. Many of them, especially those taken near the equator, showed a pronounced stratification indicating changes of surface conditions affecting the distribution of plankton organisms. A special feature on our echograms near the regions of divergence at the surface were diffusely reflecting layers in a depth of 100–250 metres, presumably fish shoals or masses of other pelagic organisms. Attempts to sample these reflecting layers failed for lack of suitable gear.

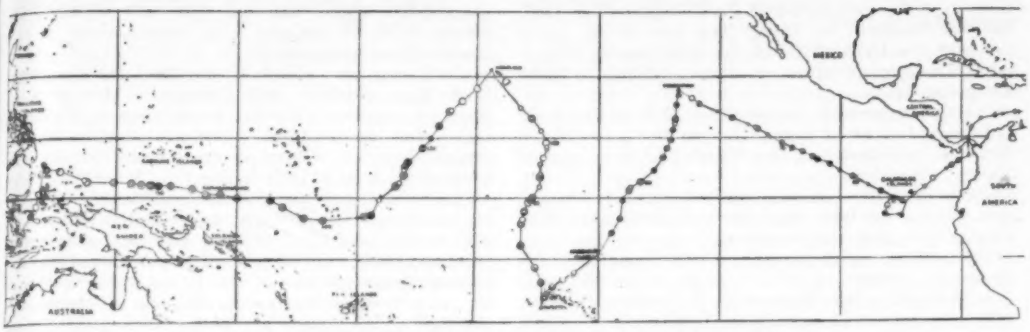
Landings made at different ocean islands afforded opportunities for making botanical collections and photographic studies of animals and plants.

Measurements of the thickness of sediment by means of recording echoes from exploding depth charges were made frequently along our course. Except near Panama, where higher values were found, no reflecting layers could be discovered below the 1,000-ft. level, in striking contrast with the much deeper echoes found in the Mediterranean and in the open Atlantic Ocean.

After proceeding through the Sunda Archipelago to Soerabaya, raising sediment cores displaying volcanic ash layers and taking hydrographic soundings under way, the expedition started on its cruise into the Indian Ocean on February 18, 1948, from Bali. Strong winds, approaching hurricane force in the squalls, made work impossible during the first week; but afterwards weather conditions were ideal. Such was not the case, however, with the state of the sea bottom, the ruggedness of which made both core sampling and measurements of sediment thickness precarious. The number of cores raised from the eastern Indian Ocean was therefore unexpectedly small—a total length of only 60 metres—and the loss of instruments was relatively heavy.

An interesting feature on our echograms was a perfectly flat bottom at a depth of about 4,300 metres, which extended for several hundred nautical miles from near the equator towards the coast of Ceylon, where the depth over long stretches did not vary by more than a few fathoms. Here the core sampler was broken in two, proving that the bottom was hard, with very thin cover of sediment (an extensive lava bed ?).

Following from Colombo a course towards the south-south-east, we again passed over the southern hemisphere, afterwards setting course for the Seychelles. The cores raised from the western Indian



Track of the *Albatross* across the Pacific. The circles indicate the stations occupied

Ocean were more numerous than in its eastern parts; and especially after leaving the Seychelles on a northerly course over the Somali Deep they displayed very pronounced stratification. In the Gulf of Aden as well as in the southern part of the Red Sea in its northern part, the rocky nature of the bottom made core-sampling precarious—the lowest parts of the cores frequently gave off a smell of sulphureted hydrogen, indicating a deficient oxygenization of the bottom waters.

As earlier in the Pacific, our numerous soundings of the thickness of sediment made in the Indian Ocean gave very moderate depths for the reflecting layer, rarely exceeding 200 metres and frequently less than 100 metres.

The hydrographic soundings included two sections across the equatorial current system, where again indications of fish-shoals (or other densely packed pelagic organisms) were found on the echograms. The *Albatross* was considerably delayed coming up the Red Sea by a strong northwester, and arrived at Suez on May 8, having thus devoted two and a half months to the Indian Ocean and to the Red Sea.

OBITUARIES

Sir Clifford Paterson, O.B.E., F.R.S.

Sir Clifford Copland Paterson, director of the Research Laboratories of the General Electric Co., Ltd., Wembley, died at the Watford Peace Memorial Hospital on July 26, shortly after returning from Australia, where he had been acting as contact between British and Australian scientific bodies.

Born on October 17, 1879, Paterson was educated at Mill Hill School and Finsbury Technical College under Silvanus Thompson. After serving a four-year apprenticeship in an engineering works in London he obtained further practical experience in Glasgow and at the Oerlikon Works in Switzerland, going afterwards to Faraday House under Dr. Alexander Russell. From 1903 until 1919 he was principal assistant to Sir Richard Glazebrook at the National Physical Laboratory, and was responsible for the electro-technical and photometric departments. Under his guidance these departments made outstanding contributions in precision methods of measuring electrical power and the establishment of the international standard of light. The Paterson–Walsh electric height finder for indicating automatically the heights of aircraft was developed during the First World War.

Paterson joined the General Electric Co., Ltd., in 1919 to establish the research laboratories of that Company, of which he was made a director in 1941. The progress of so highly technical an industry as electrical engineering depends essentially on scientific research, and the research laboratories which grew up around the achievements and personality of Paterson are representative of the finest of their kind. Starting with a staff of twenty-nine, the General Electric Research Laboratories now employ 1,750 people. Working under the inspiration and guidance of Paterson a distinguished team have made valuable contributions to developments ranging from heavy engineering to electronics. In lighting and vision, fields in which Paterson's greatest personal contributions to science were made, they have been outstanding, as well as in many other branches of applied physics.

The successful prosecution of the War demanded the speedy solution of new problems requiring the application of scientific principles. Radar was a notable example—employed first for the detection of enemy aircraft, then for naval purposes for detection and intricate gun ranging. In this and in many other directions, the facilities and the personnel of the General Electric research organisation under Paterson's direction were a great national asset.

Paterson was a man of great personal charm. His high principles and great integrity in his business, professional and personal relations were so well recognized by all with whom he came into contact that there is no need to stress them. His wide interests and the confidence imposed in him and the esteem with which he was regarded are reflected in the numerous high offices which he held in his profession, and the honours and awards conferred upon him. He was a past president of the Institution of Electrical Engineers, the Institute of Physics, the Electrical Research Association, the Illuminating Engineering Society, the International Commission on Illumination, the Institution of Illumination Engineers in Charge, and the Junior Institution of Engineers. He had been vice-president of the Royal Institution and chairman of council of the British Standards Institution. He was on the Advisory Council of the Department of Scientific and Industrial Research and a member of the Executive Committee of the National Physical Laboratory. He received the degree of D.Sc. (*honoris causa*) of the University of Birmingham in 1937, he was elected to the fellowship of the Royal Society in 1942, awarded the Faraday Medal of the Institution of Electrical Engineers in 1945, and the Ewing Medal by the

Council of the Institution of Civil Engineers in 1947. He was knighted in 1946. The last of his many honours, the Gold Medal of the Illuminating Engineering Society of America, was presented shortly before his death.

He was immensely proud of the City of London's tribute to him when during the last two years of the War he was Master of the Worshipful Company of Tallow Chandlers.

Paterson was a notable and delightful lecturer, and was at his best when his subject lent itself to experiment and demonstration. Among his outstanding lectures and papers may be mentioned the Faraday Lecture of the Institution of Electrical Engineers, "The Free Electron"; the Guthrie Lecture, "The Appraisement of Lighting"; the J. J. Thomson Jubilee Lecture, "The Electron Liberated"; and the British Association York Meeting, "The Use of Photocells".

Opportunities for relaxation and recreation to a man of Paterson's capacity for devotion to the service of his Company and the profession of which he was so distinguished a member were few; but his hobbies of gardening and yachting were a never-failing source of interest and delight to him. His garden, which Lady Paterson and he planned themselves, and the original formation of which was largely the result of their own labours, was much admired by all who were privileged to see it. The majority of his holidays were spent in his yacht on the River Deben at Waldringfield.

By Paterson's death the engineering profession suffers an inestimable loss. The records of his work remain, and are available. Through the great organisation which he built up his influence will be perpetuated; but we shall miss his sound and mature counsel, which grew out of his accumulated experiences and widespread contacts and activities.

Lady Paterson, two sons and a daughter survive him.

A. P. M. Fleming

Mr. J. R. Cowie

On August 5, Mr. John R. Cowie died aged sixty-six leaving a widow, two sons and one daughter. Chairman of the Council of the Electrical Research Association since the spring of this year, he had been a member of the Council since 1924. This long association with industrial research was particularly concerned with circuit-breaking phenomena and switchgear, which was the first and remains the largest item of research and development in the Association's programme.

Mr. Cowie was especially qualified for leadership both by experience and character. A native of Scotland, he was educated in Edinburgh (Watson's and the Heriot-Watt College) and Glasgow. Apprenticed to William Thomson and Co., he also worked with the British Electric Plant Co., and William Beardmore and Co., before joining the Glasgow Corporation, where he was associated with the late Mr. Lackie and Sir Archibald Page and concerned, *inter alia*, with the Dalmarnock power station and the raising of steam pressures. He joined A. Reyrolle and Co. twenty-seven years ago and was southern area manager at the time of his death. During this period he was associated with most of the great electrical developments in London and in the South and West of England and Wales. He served on the Council of the Institution of Electrical Engineers during 1919–22, and in 1937 was president of the Association of Mining Electrical and Mechanical Engineers. His influence in the electrical industry was great. Few leading engineers had the same depth of experience and association with great and new projects both on the supply and the manufacturing sides. No one was more trusted or, indeed, more trustworthy. In negotiation and in matters of discretion his wise counsel and his strong principles were ever in request. His clearness of thought, sincerity and frankness of expression were nevertheless allied to great kindliness. He was a loyal friend and his help was freely given to those who approached him. His subordinates thought as highly of him as his colleagues. He was esteemed not only by engineers but also by those he met in his many sports and hobbies—rugby, hockey, golf, fishing, horticulture and dog-breeding. His convictions inspired respect and his character affection.

S. Whitehead

We regret to announce the following deaths:

Dr. P. R. Lowe, O.B.E., formerly keeper in charge of ornithology, British Museum (Natural History), on August 18, aged seventy-eight.

Prof. A. F. C. Pollard, emeritus professor of physics in the Imperial College of Science and Technology, University of London, on August 15, aged seventy.

Prof. S. W. J. Smith, F.R.S., emeritus professor of physics in the University of Birmingham, on August 20, aged seventy-seven years.

NEWS and VIEWS

Sociology in the London School of Economics: Prof. D. V. Glass

The University of London has just established a new chair of sociology, tenable at the London School of Economics, and has elected Dr. D. V. Glass as the first occupant. This, the third chair in sociology in the School, is designed to promote teaching and research in the sociology of contemporary society and in current methods of collecting and analysing data obtainable by field studies and social surveys. It is therefore a post which offers great opportunities, and Dr. Glass' experience is particularly relevant. He is well known as a demographer of international repute, his most substantial work in this field being "Population Policies and Movements in Europe". He has for many years been research secretary of the Population Investigation Committee and was put in charge of the Family Census by the Royal Commission on Population. His interests have always been more in the social aspects of population than in pure statistical demography. He served his apprenticeship in social research under Prof. Lancelot Hogben, undertaking studies of educational opportunity in Great Britain, and he also published a little book on "The Town" in 1935. All this suggests that he is likely to turn his attention to such questions as family and household structure, local and occupational groups, and social mobility and stratification. These are all eminently subjects for the study of which the chair has been instituted.

The British Institute of Archæology, Ankara: Mr. Seton Lloyd

MR. SETON LLOYD, who (as announced in *Nature* of August 14, p. 250) has been elected to the directorship of the recently founded British Institute of Archæology in Ankara, started his career as architectural assistant to Sir Edwin Lutyens, and gained his early archæological experience in Egypt during the late 'twenties. During 1930–37 he worked under Dr. Henri Frankfort, as field supervisor to the Iraq Expedition of the Chicago Oriental Institute, and there gained an exceptionally detailed knowledge of mound-excavation on a wide variety of Mesopotamian sites. During this period he had the satisfaction of recovering many now famous art treasures from the rich Sumerian temples of Tell Asmar and Tell Ajrab. Next came two seasons with the Neilson Expedition under Prof. J. Garstang at Mersin in Turkey, where a stratified excavation of extreme complexity gave full scope to his particular talent. Since 1939, as technical adviser to the Directorate of Antiquities in the Government of Iraq, he has been indirectly responsible for a succession of astonishingly successful excavations, which have not only preserved the continuity of archæological discovery, but also raised his Department from a mere administrative service to a unique position as a research institution. Indeed, it would be difficult to over-estimate the debt which Mesopotamian archæology already owes to Mr. Lloyd's technique and the new generation of Iraqi excavators to his guidance. His name is now coupled with those of Mallowan and Woolley as one of the most gifted and successful excavators of our age. On him devolves the task of training those of the coming generation, and it could not be in better hands. His publications show him to be a good all-round archæologist and good artist, with a scholarly as well as a scientific outlook. The new Institute thus makes an auspicious start.

Botany in Nigeria: Prof. F. W. Sansome

THE new University College in Nigeria is fortunate to have secured Dr. F. W. Sansome as its first professor of botany. Dr. Sansome received his undergraduate training in Edinburgh as an agriculturist. Upon this foundation he added, at first in Glasgow and later at the John Innes Horticultural Institution, a thorough training in botany and genetics. At this time Dr. Sansome carried out important work on tetraploidy in tomatoes, and published (with Dr. Philp) "Recent Advances in Plant Genetics", which rapidly ran through two editions. He then became senior lecturer in the Botany Department in the University of Manchester, and assistant director of the Experimental Grounds, with responsibilities in horticultural botany and genetics. He devoted his energy, with great success, to the building up of facilities for horticultural research, and the Jodrell Bank Station owes its efficiency to Dr. Sansome's work. Dr. Sansome's infectious enthusiasm has endeared him to horticulturists and students in the north of England, and his wisdom and wit and generosity are greatly appreciated by his colleagues. The good wishes of professional botanists and a large general public will accompany him on his new venture. It is a pleasure to know that his wife, who is distinguished for her research on cytology, is to be a research fellow in Ibadan, and will continue her work there.

Veterinary Science in Bristol: Prof. F. Blakemore

IN 1943 the Committee on Veterinary Education, of which Dr. T. Loveday was chairman, recommended that a new school of veterinary science should be established in the University of Bristol. With the concurrence of the Ministry of Agriculture and Fisheries and of the University Grants Committee, the University has undertaken to carry out this recommendation. Plans are far advanced for the additional buildings required, and the small estate of Langford is available as a field station. It is proposed to admit students to the first year of study in the autumn of 1949. The University has recently appointed, as its first professor of veterinary medicine, Mr. F. Blakemore, who is at present superintending veterinary investigation officer for England and Wales. Mr. Blakemore received his veterinary education at the Universities of Liverpool and Manchester. After some experience in practice he served as veterinary officer for the county of Glamorgan, and as veterinary investigation officer for the Eastern Provinces. In 1946 he was appointed to the post he now relinquishes. He has been responsible for the teaching of general hygiene in the University of Cambridge. Mr. Blakemore has carried out extensive work on fowl paralysis and on various diseases of lambs, calves and pigs. He was the first to identify fluorine poisoning of stock in Great Britain and has traced its relation to industry. Recently he has been engaged in the study of mineral deficiency diseases in cattle.

Marin Mersenne (1588–1648)

ON September 1 occurs the tercentenary of the death of the French ecclesiast, mathematician and philosopher, Marin Mersenne, whose correspondence with his contemporaries, published in 1933–37, sheds much light on the history of physical science. Born on September 8, 1588, at La Soultière, Sarthe, he was educated at the Jesuit College at La Flèche, where for a short time he had Descartes—eight years his junior—as a school-fellow. From La Flèche, Mersenne went to Paris to study at the Sorbonne, and about 1616 entered the religious order of Minim Friars, an offshoot of the Franciscans. From 1616 until 1619 he was professor at the College of Nevers and thence onwards was superior of the Convent of his Order in Paris. He travelled into Germany, Holland and Italy, translated Galileo's "Mechanics", and held small gatherings of mathematicians and the like in his room in the Convent, thus anticipating the inauguration of the Royal Academy of Sciences.

Auguste Henri Forel

NEUROLOGIST, psychiatrist, entomologist, eugenist, temperance and penal reform advocate, Auguste Henri Forel was born a century ago, on September 1, 1848, at Morges, Canton Vaud, in Switzerland. His childhood studies of ants culminated in the publication, at the age of twenty-six, of "Les Fourmis de la Suisse", of which Darwin confessed that seldom in his life had he been more interested by any book. Studying medicine at Zurich, Forel specialized in psychiatry and was appointed professor of psychiatry in the University and director of the Insane Hospital. The more important works of this indefatigable and versatile man include "Der Hypnotismus und die Suggestive Psychotherapie" (1889), "Hygiene der Nerven und des Geistes" (1903) and "Die Sexuelle

Frage" (1905). The last was translated into sixteen languages, and the year of his death witnessed the publication of a sixteenth edition. It was described by Havelock Ellis as "without doubt the most comprehensive, and taking into account its many-sidedness, perhaps the ablest work which has yet appeared on the sex question". When he was fifty, Forel gave up teaching and devoted himself to the pursuit of his bewildering variety of interests. In 1912 he had a stroke, which resulted in permanent paralysis of his right hand. To the literature of autopathography he contributed an interesting account of his dysphasia in the *Journal für Psychologie und Neurologie*, of which he was founder and editor. His autobiography "Out of My Life and Work" (English translation, 1937) is a frank and fascinating self-portrait of one of the most picturesque scientific figures of modern times. He died in 1931.

The *Philosophical Magazine*: 150th Anniversary

THE *Philosophical Magazine* was first published in 1798, and the board of directors and the editorial board have every reason to be proud of the journal's record during its long life of a hundred and fifty years. The title-page to the first volume indicates a breadth of interest "comprehending the various branches of science, the liberal and fine arts, agriculture, manufactures and commerce". Succeeding volumes of the *Magazine* have achieved for it an international reputation as a scientific journal in the realm of physical and mathematical science. David Brewster, John Tyndall, William Thomson, Oliver Lodge, J. J. Thomson are names to be found in the list of editors who succeeded Alexander Tilloch and Richard Taylor, and it is not surprising that such men of science have been responsible for the publication of important papers by research workers in various fields, including those of relativity and atomic physics. The traditionally high standard of the *Philosophical Magazine* has been well maintained, and we wish the periodical every success on the journey towards the two hundredth anniversary of its foundation.

To mark the hundred and fiftieth anniversary of the founding of the *Philosophical Magazine*, a special commemoration number has been edited by Dr. Alan Ferguson under the general title "Natural Philosophy through the Eighteenth Century and Allied Topics" (Pp. viii+164. London: Taylor and Francis. 15*s*.). This is a most useful survey, and includes articles on astronomy through the eighteenth century by Sir H. Spencer Jones, physics by Prof. Herbert Dingle, chemistry by Prof. J. R. Partington, and mathematics by Dr. J. F. Scott. An appropriate review by Engineer-Captain Edgar C. Smith provides interesting material on the achievements of civil engineering. Among the allied topics dealt with are: scientific instruments by Mr. Robert S. Whipple, the scientific periodical from 1665 to 1798 by Dr. Douglas McKie, and the teaching of the physical sciences at the end of the eighteenth century by Dr. F. Sherwood Taylor. The whole volume is both interesting and instructive, containing a wealth of information which enhances its value as a book of reference.

The Night Sky in September

NEW moon occurs on Sept. 3d. 11h. 21m., U.T., and full moon on Sept. 18d. 09h. 43m. The following conjunctions with the moon take place: Sept. 4d. 18h., Mercury 3° S.; Sept. 6d. 22h., Mars 0·7° S.; Sept. 10d. 13h., Jupiter 4° N.; Sept. 29d. 13h., Venus 6° S.; Sept. 30d. 05h., Saturn 4° S. In addition to these conjunctions with the moon, the following conjunctions take place: Sept. 9d. 10h., Saturn in conjunction with Regulus, Saturn 0·8° N.; Sept. 20d. 16h., Mercury in conjunction with Spica, Mercury 0·2° S. Mercury sets at 19h. 15m., 18h. 45m. and 17h. 52m. at the beginning, middle and end of the month, respectively, and is too close to the sun for favourable observation. The planet reaches its greatest eastern elongation on Sept. 25. Venus is a morning star, rising at 1h. 15m., 1h. 30m. and 1h. 55m. at the beginning, middle and end of the month, respectively; it has a stellar magnitude of approximately − 3·8 throughout most of September, and can be observed with phase a little more than half moon most of the time. The planet attains its greatest western elongation on Sept. 3. Mars sets at 20h. 10m. and 18h. 50m. at the beginning and end of the month, respectively, and is too close to the sun for favourable observation. Jupiter can be seen for some time after sunset, the times of setting being 22h. 25m. and 20h. 40m. on Sept. 1 and 30, respectively, but the planet lies rather low for good observation in northern latitudes. Saturn rises at 4h. 10m. and 2h. 35m. at the beginning and end of the month, respectively, and can be seen as a morning star, stellar magnitude 0·9. One occultation of stars brighter than magnitude 6 occurs as follows: Sept. 27d. 01h. 43·5m., 47 Gemi. (*R*), where *R* refers to reappearance; the latitude of Greenwich is assumed. Autumnal equinox commences on Sept. 23d. 03h.

Announcements

DR. G. H. S. BUSHNELL has been appointed curator of the Museum of Archæology and Ethnology in the University of Cambridge.

Mr. B. C. Clayton and Mr. V. D. O. Smyth have recently been appointed advisory officers at the Research Station of the Board of Greenkeeping Research, St. Ives Research Station, Bingley, Yorkshire.

UNDER the auspices of the Society of Chemical Industry, a conference on "Dust in Industry" will be held at the University of Leeds during September 28–30. Further information can be obtained from the General Secretary, Society of Chemical Industry, 56 Victoria Street, London, S.W.1.

A CONFERENCE on "Modern Applications of Liquid Fuels" will be held at the University of Birmingham during September 21–23, under the joint auspices of the Institute of Petroleum and the Institute of Fuel. The president will be Mr. J. A. Oriel. Further information can be obtained from Mr. R. W. Reynolds-Davies, General Secretary, 18 Devonshire Street, London, W.1.

A CONVENTION on "High Vacua" will be held at Gleneagles, Perthshire, during October 12–13, under the presidency of Sir Charles Darwin. Further information can be obtained from Mr. L. L. Maitland, British-American Research, Block E.2, Hillingdon North, Glasgow, S.W.

A DISCUSSION on "Meteors" will be held in the Physical Laboratories of the University of Manchester on September 9. It will be opened by Dr. F. L. Whipple of Harvard University; other speakers will include Mr. J. P. M. Prentice, Dr. J. G. Porter, Mr. N. Herlofson and Dr. A. C. B. Lovell. Further information can be obtained from Dr. Lovell at the above Laboratories.

LETTERS TO THE EDITORS

The Editors do not hold themselves responsible for opinions expressed by their correspondents. No notice is taken of anonymous communications

Behaviour of a Particle of Very Small Mass in a Magnetic Field

It would seem at first sight that a particle of very small mass, such as accompanies β-disintegration or electron-capture, and significant magnetic moment μ, would be very difficult to observe. According to Bethe[1], it should have a fairly high ionizing power and a correspondingly small penetration into matter. Moreover, if it already possesses a charge e, the uncertainty principle should play a part in all cases where experimental evidence on μ would be sought[2]. However, for an ultra-relativistic particle (that is, a particle with a high ratio of kinetic mass to rest mass) special considerations come into play which may modify the generally accepted conclusions.

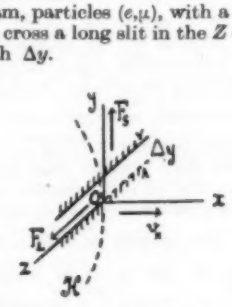
A Dirac particle can be considered as a spherule which is both magnetized and carries an electric charge. As Frenkel[3] has pointed out, if the particle has a magnetic moment $\vec{\mu}$, an electric moment $\vec{\pi}$, of the same order of absolute value, must necessarily appear. Moreover, when the speed approaches c, the three vectors $\vec{\mu}$, $\vec{\pi}$ and $\vec{c}$ tend to become orthogonal[4]. The magnitude of the moment $\vec{\mu}$ should vary with the speed if it could have any direction whatever. However, in the case where the moment $\vec{\mu}$ is orthogonal to the direction of the displacement, the former has the properties of invariance, as described by Louis de Broglie[5], who pointed out that the densities of moments $\vec{\mu}$ and $\vec{\pi}$ form the six components of an antisymmetrical tensor of the second order: the main moments that are obtained by integration from these densities have invariant values. Thus, in the relativistic case, moment $\vec{\mu}$ would always tend to follow the orthogonal direction and to be invariant in this.

Let us write the uncertainty relation in a new form that is better adapted to high speeds:

$$\Delta x \,.\, \Delta\eta \geqslant \frac{h}{m_0 c}, \text{ where } \Delta x \,.\, \Delta v \geqslant \frac{h}{m_0 \eta^2} \qquad (1)$$

$$(\text{for } \Delta p = m_0 c \,.\, \Delta\eta = m_0 \eta^3 \, \Delta v).$$

In the diagram, particles (e,μ), with a speed v_x in the direction Ox, cross a long slit in the Z direction which has the width Δy.



The Lorentz force at the origin O is $F_L = ev_x H(O)$. The width Δy of the slit introduces in this force an uncertainty

$$\Delta F_L = e\left[v_x\left(\frac{\partial H}{\partial y}\right)\Delta y + H(O)\Delta v_x\right],$$

which we must compare to the force F_S due to spin. The ratio of these forces, with $\mu = eh/4\pi m_0$, will be

$$\frac{\Delta F_L}{F_S} = \frac{4\pi m_0}{h}\left[v_x \Delta y + \frac{H}{\partial H/\partial y}\,\Delta v_x\right], \qquad (2)$$

putting, from (1),

$$\Delta y \geqslant \frac{h}{m_0 \eta^3 \Delta v_y} \text{ and } \Delta v_x \geqslant \frac{h}{m_0 \eta^3 \Delta x}. \qquad (3)$$

(2) then becomes

$$\frac{\Delta F_L}{F_S} \geqslant \frac{4\pi m_0}{h}\left[\frac{h}{m_0\eta^3}\cdot\frac{v_x}{\Delta v_y} + \frac{h}{m_0\eta^3}\,\frac{H}{\partial H/\partial y}\,\frac{1}{\Delta x}\right], \text{ or}$$

$$\frac{\Delta F_L}{F_S} \geqslant \frac{4\pi}{\eta^3}\left[\frac{v_x}{\Delta v_y} + \frac{H}{\partial H/\partial y}\,\frac{1}{\Delta x}\right].$$

The term in brackets being obviously greater than 1, we finally get

$$\Delta F_L/F_S \geqslant 4\pi/\eta^3, \qquad (4)$$

and the magnetic moment μ will be observable if

$$\eta^3 \geqslant 4\pi, \qquad (5)$$

a condition that is obviously fulfilled for every relativistic particle.

The magnetic moment of a charged light particle might thus be found.

Even if we deny invariance to the magnetic moment and allow that its absolute value might decrease as the kinetic mass of the particle increases, the various expressions which have been given[6] for the conditions of observability remain, with a power of η diminished by one unit, and the conclusions are unchanged.

The foregoing considerations are of a very general character. The question will be examined afresh with the Dirac method. On the other hand, I shall shortly show that a relativistic particle may give a weaker ionization when traversing matter than was previously thought. This arises both because of the orthogonal relation of the electric moment $\vec{\pi}$ to $\vec{\mu}$ and $\vec{c}$, and because of the contracting of the magnetic and electric lines of force in a plane normal to the direction of its displacement.

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Feret's Statistical Diameter as a Measure of Particle Size

Various measures of the size of irregularly shaped particles as seen in profile under the microscope have been used, chosen according to their theoretical significance or practical ease of measurement. These include, using Heywood's notation[1,2]: (i) the diameter of the circle of equal area, d; (ii) the diameter of the circle of equal perimeter, D; (iii) the length of line bisecting the profile area (Martin's statistical diameter[3]), M; and (iv) the perpendicular distance between parallel tangents touching opposite sides of the profile (Feret's statistical diameter[4]), F. M and F

are determined for randomly oriented particles, thus giving an average value over all possible orientations. d is usually regarded as the ideal measure of particles seen in profile, but is somewhat difficult to determine experimentally with precision. It is, however, common practice when sizing very small particles to estimate d visually by comparing them with standard reference circles on a Patterson and Cawood or similar type of eyepiece graticule[5,6]. M and F are convenient to measure in practice with aid of an eyepiece scale or filar micrometer, and have been extensively used by various workers. D, or rather the ratio D/d, termed by Heywood[1] the 'contour ratio', and its reciprocal called the 'degree of circularity' by Wadell[7], have been used in discussing the shape and hydrodynamical properties of particles. For these purposes D has usually been determined by direct perimeter measurement of the projected images of particles. It does not appear to have been adopted intentionally in any work known to me as a direct single measure of particle size.

In fact, it can be shown that D and F are equivalent measures provided that the particle profile is non-re-entrant, a condition which is usually satisfied. This simple identity seems to have been overlooked hitherto in particle-size work. Elementary calculation will demonstrate the relationship for simple geometrical outlines, for example, triangle or rectangle, orientated in all possible directions. The proof in the more general case follows readily by considering each element of the perimeter separately. The three-dimensional equivalent of this result is already well known, namely, that the mean projected area of a three-dimensional particle averaged over all orientations is equal to one quarter of the total surface area of the particle, again with the condition of non-re-entrancy. This latter relationship has been much used in the determination of the specific surface of suspended particles by light obscuration methods[8]. Both results follow from two mathematical theorems given by Cauchy in 1841 [9]. The second of these theorems is discussed by Vouk[10].

In a recent paper, Heywood[2] has discussed the various methods of measuring microscopical particles. Judging other measures by comparison with the mean projected diameter, d, as standard, he concludes: "The Feret definition of statistical diameter is not recommended on account of the large positive error introduced for elongated particles". Interpretation of the Feret diameter as $1/\pi$ of the perimeter shows that no general correspondence with d can obtain for particles of differing shape; but it gives this statistical diameter an important new significance, particularly in connexion with the specification of particle shape and correlated properties.

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Projected Area of Convex Bodies

In connexion with photometric determination of specific surface of finely divided material, it is essential to know the relation between the projected area of particles, which is actually measured, and the corresponding surface area. The solution of this problem was first given by A. Cauchy in his "Memoire sur la rectification des courbes et la quadrature des surfaces courbes" (Paris, 1832)[1]. A short account of his results in the form of theorems was later published in the *Comptes rendus*[2], but no formal proof was given. It is the latter paper which is usually referred to in connexion with the above problem.

The relevant theorem states that

$$S = 4\overline{A}, \qquad (1)$$

where S is the surface area and $\overline{A}$ the average projected area of the convex body. The average is taken over all possible orientations in space. Although this result has been much used and discussed by many experimental and theoretical workers[3], there still seems to be much confusion and uncertainty as to its general validity. Thus in *Nature* recently[4], Dr. B. A. Scott says that it can be shown that the ratio of surface to projected area for a rectangular parallelepiped in random motion is $18\pi/(8+\pi)$ independent of the relative lengths of the axes. Dr. Scott uses this result to compute the surface area of calcined and hydrated alumina, and obtains a very good agreement between the estimates of the surface area obtained from optical measurement and other methods. Since similar work is going on in our laboratory, Dr. Scott's statement induced us to examine once more the literature on Cauchy's theorem, and we came to the conclusion that an error must have crept into Dr. Scott's calculations.

Since the original Cauchy's papers are not easily accessible and the discussion of the problem presented therein is not always easy to follow, we think it worth while to give a short proof of equation (1) in a slightly different form from that given by Cauchy.

Consider a convex body having a surface area S. Suppose there are no re-entrant surfaces, that is, the surface S cannot be pierced by a straight line on more than two points. We divide S into a large number of infinitesimal surface elements, which can be represented by a vector $d\vec{\sigma}$ having the direction of the outward normal to the surface element and the magnitude numerically equal to its area. The projection dA of such an element on a fixed plane P specified by its normal $\vec{n}$ is given by the absolute value of the scalar product $|\, d\vec{\sigma} \,.\, \vec{n}\,|$. For the sake of simplicity, we shall suppose that the plane P is perpendicular to one of the axes (for example, the x-axis) of a rectangular co-ordinate system x,y,z. The components of the vectors $d\vec{\sigma}$ and $\vec{n}$ will then be given by: $d\vec{\sigma} = d\sigma\,(\sin\vartheta\cos\varphi\vec{i} + \sin\vartheta\sin\varphi\vec{j} + \cos\vartheta\vec{k}$, and $\vec{n} = \vec{i}$, where $\vec{i}, \vec{j}, \vec{k}$ are unit vectors in directions of the co-ordinate axes, and ϑ and φ are the angles which the vector $d\vec{\sigma}$ forms with positive z and x axes. Since all orientations of the surface element are equally likely, the average value of the projection of $d\vec{\sigma}$ on the plane P is given by:

$$\overline{dA} = \frac{1}{4\pi}\iint_{\omega} |\vec{d\sigma} \cdot \vec{n}|\, d\omega, \qquad (2)$$

where $d\omega$ is the element of solid angle ($= \sin\vartheta\, d\vartheta\, d\varphi$) and the integration has to be carried out over the total solid angle 4π. Now in optical problems the surface element will contribute to the projection of the body only if its orientation is such that the angle between $\vec{d\sigma}$ and $\vec{n}$ is less than $\pi/2$. Therefore, the right-hand side of equation (2) should be multiplied by a factor 1/2. Thus we have

$$\overline{dA} = \frac{d\sigma}{2\pi}\int_0^{\pi}\int_0^{\pi/2} \sin^2\vartheta\cos\varphi\, d\vartheta\, d\varphi. \qquad (3)$$

The integration of (3) gives

$$\overline{dA} = 1/4\, d\sigma. \qquad (4)$$

Now if there are no re-entrant surfaces, we can consider the elements of the surface of a convex body as giving equal contributions independent of each other to the total average projected area of the body, and we can write

$$\overline{A} = 1/4 \iint_{\sigma} d\sigma, \qquad (5)$$

and the proof of the relation (1) is completed.

In the presence of re-entrant surfaces, equation (5) is not valid, since the contributions from different surface elements cannot be taken as independent. Our assumption that a given surface element contributes to the projected area only if the angle between vectors $\vec{d\sigma}$ and $\vec{n}$ is less than $\pi/2$ is no longer true. There will be some orientations of the body in which some of the surface elements will not make any contribution, although their normals form with the normal of the fixed plane P an angle less than $\pi/2$, because of the obscuration effect. Therefore the ratio of the projected to the surface area for such bodies will always be less than 1/4.

For polyhedra it is not necessary to subdivide the surface in infinitesimal elements $d\sigma$. It suffices to calculate the contribution from each of the n faces separately, and to replace the integral in equation (5) by a summation.

The validity of relation (1) can also be shown by computing the projected area of the body as a whole, and integrating over all possible orientations. This method was used by Cauchy in his original paper (1) in the case of an ellipsoid. The calculation is easy for such simple bodies as the cube, the parallelepiped, the prism or the cylinder, but for more complicated polyhedra it becomes very tedious.

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Proton Bombardment of Fluorine

Capture γ-rays have been detected in the proton bombardment of most of the light nuclei from Li^7 to Cl^{37}. The yield from a thick target for a single level in the compound nucleus is proportional to:

$$\Gamma_p\Gamma_\gamma/\Gamma. \qquad (1)$$

The presence of a competing mode of disintegration only reduces this yield as much as it increases the total width Γ. Thus, in the case of F^{19}, the most probable transmutation is the short-range α-emission:

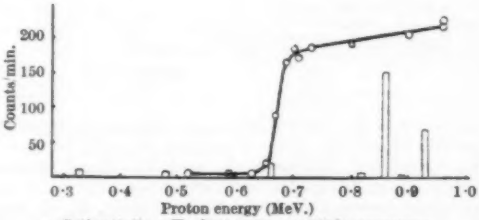
$$F^{19} + H^1 \rightarrow Ne^{20*} \rightarrow O^{16*} + He^4$$
$$O^{16*} \rightarrow O^{16} + h\nu\ (6\ \text{MeV.}); \qquad (2)$$

but this should not decrease the probability of γ-emission from the levels of Ne^{20} produced by protons of more than about 600 keV., for in this energy region we expect the proton width Γ_p to exceed the short-range α-particle width Γ_α; and the total width Γ will be determined largely by the former.

The high yield of 6 MeV. γ-rays from (2) does, however, make it difficult to observe the expected capture γ-rays:

$$F^{19} + H^1 \rightarrow Ne^{20*} \rightarrow Ne^{20} + h\nu \qquad (3)$$
$$(Q = 12{\cdot}8\ \text{MeV.}).$$

We used the (γ,n) reaction in Cu^{63} as a threshold ($10{\cdot}9 \pm 0{\cdot}3$ MeV.)[1] detector, counting the resulting 10·5-min. activity on thin-wall aluminium β-counters. The accompanying graph gives our results, and also indicates the positions and relative yields of the resonances for process (3)[2]. The shape of the rise between 630 and 700 keV. was compared with the rise in the yield of the 6 MeV. γ-rays, measured simultaneously with a Geiger–Müller γ-counter, and agreement was good. The slow rise between 700 and 960 keV. may be the result of a dirty target, or may indicate the emission of γ-rays from the broad levels[3,4] of Ne^{20}. In either case, it is clear that there is no yield of high-energy γ-rays from the other resonances of reaction (3), comparable with the yield at the 660 keV. resonance.



o, Cu^{63} activity; ⌐, short-range α-particle resonances

The energy available for this transition, 13·4 MeV., does not greatly exceed the threshold of the detector; and Dee, Curran and Strothers[5] found no γ–γ coincidences from fluorine bombarded with protons. It is thus probable that the γ-ray that we detect is the full energy transition to the ground-state.

Having the 590 and 862 keV. resonances available for background runs with the high intensity of 6 MeV. γ-rays alone present, we were able to measure the higher energy γ-rays by the coincidence absorption method, using two Geiger–Müller counters. By this means the angular distribution of the capture γ-ray was found to be isotropic, intensities at 0°, 45° and 90° to the proton beam direction being equal within a probable error of 10 per cent. The yield at the 660 keV. resonance was estimated at $2{\cdot}2 \pm 0{\cdot}8$ per

cent of the 6 MeV. γ-rays, giving a radiation width of the order of 2 eV. for this level of Ne^{20}, and less than 0·1 eV. for the others up to 1 MeV. proton energy. This yield is consistent with our measurements with the copper detector if the (γ,n) cross-section of Cu^{63} is about $1{\cdot}5 \times 10^{-27}$ cm.[5] at this energy[6].

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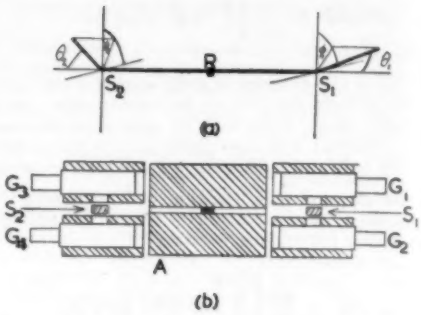
Polarization of Annihilation Radiation

An attempt has been made to detect the relative polarization of the two photons of energy 0·51 MeV. produced in the annihilation of slow positrons. If pairs of quanta from a source of annihilation radiation at R (Fig. *a*) are scattered at S_1 and S_2, theory[1–3] predicts an angular distribution of quanta after Compton scattering given by the formula

$$N(\theta_1\varphi_1\theta_2\varphi_2)d\Omega_1 d\Omega_2 = k\left\{\frac{[(1-\cos\theta_1)^2+2]\,[(1-\cos\theta_2)^3+2]}{[2-\cos\theta_1]^3\,[2-\cos\theta_2]^3} - \frac{\sin^2\theta_1\,\sin^2\theta_2\,\cos 2(\varphi_1-\varphi_2)}{[2-\cos\theta_1]^3\,[2-\cos\theta_2]^3}\right\}d\Omega_1 d\Omega_2,$$

where θ_1 and θ_2 are the angles through which the quanta are scattered, φ_1 and φ_2 are the azimuthal angles measured in a plane perpendicular to the direction of incidence (S_1RS_2), and $N(\theta_1\varphi_1\theta_2\varphi_2)d\Omega_1 d\Omega_2$ the probability of the two quanta being scattered into elements of solid angle $d\Omega_1$ and $d\Omega_2$ in the directions $(\theta_1\varphi_1)$, $(\theta_2\varphi_2)$.

The apparatus for the experimental verification of this formula is sketched in Fig. *b*. Positron-active material, packed into an aluminium tube, is placed at the centre of the lead block A. Oppositely directed quanta pass down the collimating channel to strike the cylindrical scatterers S_1 and S_2. Lead shields define the solid angles into which quanta must be scattered to reach the Geiger counters G_1, G_2, G_3 and G_4. Coincident discharges of either G_1 or G_2 with either G_3 or G_4 are recorded when all four counters lie in the same plane (coplanar position), and when one pair of counters is rotated through 90° about S_1S_2 (perpendicular position), corresponding to mean values of $(\varphi_1-\varphi_2)$ of 0° and 90° respectively. The total numbers of discharges in each pair of counters (of which 70 per cent are due to quanta scattered by S_1 or S_2) are recorded and used to calculate corrections for source decay and chance coincidences.



Sources of Cu^{64} (12·8 hr. half-life) were prepared by deuteron bombardment of copper in the Cambridge cyclotron; each had an initial activity of about 3×10^8 positrons per sec., and gave useful counting rates over a period of 36 hours after irradiation. The results from thirteen such sources are condensed into the accompanying table. The first results were obtained with brass scatterers 1 in. long and 0·6 in. in diameter; later, aluminium scatterers of the same dimensions were used to minimize the effect of double scattering. Two different arrangements of lead shields surrounding the counters were used, the first defining rather larger solid angles for detection of the scattered quanta than the second. Corrections have been made for source decay, chance coincidences, and a background-rate of 3 per hr. due to cosmic rays. The net coincidence-rates at the beginning of each run were of order 0·5 per min. The errors quoted are standard deviations calculated assuming normal statistical fluctuations, and are compatible with the variations in the results from individual sources.

The results establish the existence of a relative polarization. Further experiments are needed, however, to determine whether the discrepancies between theoretical prediction and experimental results are merely instrumental, or due to a breakdown of theory.

The deviations appear too large to be dismissed as due to statistical fluctuations, especially as the independent results using different scatterers are all consistently lower than the theoretical predictions. Any double scattering of quanta within the scatterers would tend to reduce the observed ratio; the increase in the observed ratio with the lower density scatterers may be significant. A rigorous calculation of such an effect is not feasible; rough calculations indicate that it should not be serious. The Geiger counters are being replaced by scintillation counters; an expected twenty-fold increase in detection efficiency will permit the use of smaller scatterers of low-density material, more close defined geometry, and increased counting-rates, and so settle definitely whether or not the theoretical predictions are quantitatively correct.

Scatterer material		Brass	Brass	Aluminium
Lead shield arrangement		Wide angle	Narrow angle	Narrow angle
Counting-rate (perpendicular pos.) / Counting-rate (co-planar pos.)	(theory)	1·55	1·82	1·86
" " " "	(experimental)	1·39 ± 0·07	1·31 ± 0·17	1·51 ± 0·10

Note added in proof, August 21. The results of Bleuler and Bradt[4] are noted. Their value for the ratio of perpendicular to coplanar coincidence-rates, while in agreement with theory, has a sufficient margin of error to be compatible with the results quoted here.

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Origin of Cosmic Ray Stars

As yet, the absorption of the star-producing radiation has only been measured in air. Nevertheless, the variation of the intensity of single tracks recorded in photographic plates under various lead absorbers has been measured at high altitude and at sea-level[1,2]. The decrease of single tracks with a given lead absorber is found to be much less than the decrease of stars in an equal weight of the atmosphere. Perkins[2] has shown that the number of single tracks is proportional to the number of stars, and therefore it appears established that the range of the star-producing component of cosmic radiation expressed in gm./cm.^{2} is larger by a factor of approximately 3 in lead than it is in air.

This difference in range could be caused possibly by the difference in (*a*) density, or (*b*) atomic weight, A, of the two materials. Perkins has assumed the former and has concluded that the stars are produced by an unstable particle. It seems worth while to explore the latter possibility, as this leads to a dependence of the range of the primaries on A, not very dissimilar from that found experimentally.

Thus, it is well known that the nuclear radius is approximately proportional to $A^{1/3}$:

$$R = r_0 A^{1/3}, \text{ with } r_0 \sim 10^{-13} \text{ cm.} \qquad (1)$$

The cross-section, σ, will be πR^2, and the number of nuclei per gm./cm.^{2}, n, will be N/A, where N is Avogadro's number. Hence the mean free path for a radiation interacting strongly with the nuclei will be given by:

$$l = 1/n\pi R^2 \text{ gm./cm.}^2, \text{ or } l = A^{1/3}/N\pi r_0^2 \text{ gm./cm.}^2. \qquad (2)$$

Substituting numerical values, one obtains:

$$l_{\text{air}} = 130 \text{ gm./cm.}^2, \; l_{\text{lead}} = 311 \text{ gm./cm.}^2, \quad l_{\text{lead}}/l_{\text{air}} = 2{\cdot}5,$$

which do not differ greatly from the observed values.

Thus, as an alternative to the assumption of unstable primaries, one may equally well assume the primaries to be stable particles having a cross-section for star production given by the so-called geometric cross-section, and hence a range given by (2).

From the known constitution of the Ilford nuclear emulsion, one obtains for the range of the primaries in the emulsion on this basis:

$$l_E = 200 \text{ gm./cm.}^2 = 50 \text{ cm.}, \qquad (3)$$

since $\rho_E = 4$. Let S be the number of primaries crossing 1 cm.^{2} per day, and I the number of stars formed per c.c. per day. Then approximately:

$$S/l_E = I. \qquad (4)$$

Now, at Jungfraujoch, $I \sim 10$ stars/c.c./day, and hence:

$$S \sim 500/\text{cm.}^2/\text{day}, \qquad (5)$$

or, in other words, about 12 per cent of the total corpuscular radiation at this altitude.

This is in rough agreement with Schopper's estimate[3] of the intensity of fast neutrons, based on measurements of the number of recoil protons recorded in plates covered with paraffin. Thus, the assumption that the majority of cosmic ray stars are caused by fast neutrons is not in violent disagreement with the existing data.

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Random Association of Points on a Lattice

A LATTICE is defined to be a rectangular array of points each of which may be any one of k colours. In a previous communication[1], I have given the first and the second moments for the probability distribution of the total number of joins between points of different colours, when the probability that any point is of colour r is $p_r \left(\sum_1^k p_r = 1 \right)$ and is independent of the colour of all the other points. A join was there defined as a line between two adjacent points parallel to the axes of the lattice. The present note gives the first and the second moments for the distribution of (1) the number of joins between points of the same colour, and (2) the total number of joins between points of different colours for two- and three-dimensional lattices when all possible joins between adjacent points are included. The first distribution corresponds to Todd's distribution of 'doublets'[2].

(1) *Joins between points of the same colour, say, rth colour.*

(*a*) Two-dimensional lattice: $m \times n$ points:

$$\mu_1' = (4b - 3a + 2)\, p_r^2,$$
$$\mu_2 = (4b - 3a + 2)\, p_r^2 + 8(7b - 9a + 11)\, p_r^3 - 15(4b - 5a + 6)\, p_r^4.$$

(*b*) Three-dimensional lattice: $l \times m \times n$ points:

$$\mu_1' = (13c - 9d + 6c - 4)\, p_r^2,$$
$$\mu_2 = (13c - 9d + 6c - 4)\, p_r^2 + 2(325e - 378d + 432c - 488)\, p_r^3 - (663e - 765d + 870c - 980)\, p_r^4.$$

(2) *Total number of joins between points of different colours.*

(*a*) Two-dimensional lattice: $m \times n$ points:

$$\mu_1' = 2(4b - 3a + 2)\, \Sigma p_r p_s,$$
$$\mu_2 = 2(32b - 39a + 46)\, \Sigma p_r p_s - 8(39b - 48a + 57)\, \Sigma p_r p_s p_t - 60(4b - 5a + 6)\, \Sigma p_r^2 p_s^2 + 120(4b - 5a + 6)\, \Sigma p_r p_s p_t p_u.$$

(*b*) Three-dimensional lattice: $l \times m \times n$ points:

$$\mu_1' = 2(13e - 9d + 6c - 4)\, \Sigma p_r p_s,$$
$$\mu_2 = 2(338e - 387d + 438c - 492)\, \Sigma p_r p_s - 2(1677e - 1926d + 2184c - 2456)\, \Sigma p_r p_s p_t - 4(663e - 765d + 870c - 980)\, \Sigma p_r^2 p_s^2 + 8(663e - 765d + 870c - 980)\, \Sigma p_r p_s p_t p_u.$$

In all these expressions, $a = m + n$, $b = mn$, $c = l + m + n$, $d = lm + mn + nl$, and $e = lmn$. The summations are taken for all values of r, s, t and u such that $1 \leqslant r < s < t < u \leqslant k$.

All the distributions tend to the normal form when l, m and n tend to infinity.

The corresponding results when the lattices consist of a fixed number of points of the various colours, say $n_1, n_2, \ldots n_k$, have also been worked out. These results, being long and complicated, will be given in another communication to be published shortly.

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Difference – Differential Equations

THE general linear homogeneous difference – differential equation with constant coefficients is

$$\Lambda(y) \equiv \sum_{\mu}\sum_{\nu} a_{\mu\nu} y^{(\nu)}(t + b_\mu) = 0, \qquad (1)$$

where $0 \leqslant \mu \leqslant m$, $0 \leqslant \nu \leqslant n$, $y^{(\nu)}(t)$ is the ν-th derivative of the unknown function $y(t)$ and $0 = b_0 < b_1 < \ldots < b_m$. Particular examples of this equation have appeared in radiology[1,2], economics[3,4] and the theory of control mechanisms[5,6]. The most useful 'boundary conditions' are also the most convenient from the theoretical point of view; we suppose assigned the values of $y(t)$ in an initial interval $0 \leqslant t < b_m$. In terms of these given values, we define a function

$$\varphi(s) = \sum_{\mu}\sum_{\nu} a_{\mu\nu} \exp(b_\mu s) \times$$

$$\left\{ \int_0^{b_\mu} y^{(\nu)}(u) e^{-su} du + \sum_{\lambda=0}^{\nu-1} s^{\nu-1-\lambda} y^{(\lambda)}(0) \right\}.$$

(In particular cases this usually reduces to something fairly simple.) It is obvious that $y = \exp st$ is a solution of (1) for any s satisfying

$$\tau(s) \equiv \sum_{\mu}\sum_{\nu} a_{\mu\nu} s^{\nu} \exp(b_\mu s) = 0.$$

The zeros of $\tau(s)$ are infinite in number; but their asymptotic behaviour is readily calculable[7]. Under suitable conditions, the solution of (1) is

$$y(t) = \sum_{s} \frac{\varphi(s) \exp st}{\tau'(s)}, \qquad (2)$$

where s runs through all the zeros of $\tau(s)$. I here assume that $\tau(s)$ has no double zero; if it has, a slight modification must be made in the corresponding term. The series in (2) is convergent and its sum is $y(t)$ (i) for all t, if $a_{mn} \neq 0$ and $a_{qn} \neq 0$, and (ii) for all $t > b_m$, if $a_{mn} \neq 0$. (2) was first given by Hilb[8], but under conditions which would exclude most of the applications. A detailed proof of its validity under the conditions stated will be published shortly[9].

The most interesting question about $y(t)$ is how it behaves when t is large and, in particular, whether $y(t)$ becomes small, periodic or large. This requires a study of the zeros of $\tau(s)$. In any particular case the behaviour of the large zeros can be determined from Langer's theory[7]. If these zeros all have their real parts negative, so that the corresponding terms in $y(t)$ are damped, attention must be directed to a finite number of non-large zeros. This problem for the particular cases in which

$$\tau(s) \equiv s(s + \alpha)e^s + \beta_1 + \beta_2 s + \beta_3 s^2$$

and

$$\tau(s) \equiv s^2 (s + \alpha_1)e^s + (\beta_1 + \beta_2 s)(\alpha_1 + \alpha_2 s)$$

has been discussed by Hartree and others[5,6]. Another special case, into which the equations occurring in radiology[1] and in economics[3,4] may be trivially transformed, is the equation

$$y'(t + 1) + \alpha y(t) = 0 \qquad (\alpha > 0).$$

For this, $\tau(s) \equiv se^s + \alpha$. If $\alpha < \frac{1}{2}\pi$, all zeros of $\tau(s)$ have their real parts negative and $y(t) \to 0$ as $t \to +\infty$, whatever the initial conditions. If $\alpha > \frac{1}{2}\pi$, at least two zeros of $\tau(s)$ have their real parts positive and $y(t)$ oscillates with increasing amplitude as $t \to +\infty$, except under very special initial conditions. For $\alpha = \frac{1}{2}\pi$, there is a periodic solution $y = A \sin(\frac{1}{2}\pi t + B)$ with arbitrary A and B, and the general solution approaches this as t becomes large. There is a periodic solution for $\alpha = 2k\pi + \frac{1}{2}\pi$, where k is any whole number, but the general solution oscillates infinitely unless $k = 0$.

The non-homogeneous equation

$$\Lambda(y) = v(t), \qquad (3)$$

where $v(t)$ is a known function, can also be solved for those $v(t)$ which have a readily calculable Laplace transform. Of course, if any particular solution of (3) can be found, the problem of finding the general solution, or the solution satisfying 'boundary conditions' of our type, is reduced to the same problem for (1), just as in the theory of differential equations.

More substantial and more interesting problems are presented by linear difference – differential equations with variable coefficients[10] and by non-linear equations[11]. The only published application of such a non-linear equation known to me occurs in Lord Cherwell's investigations by probability methods into the distribution of prime numbers[12].

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April 26.

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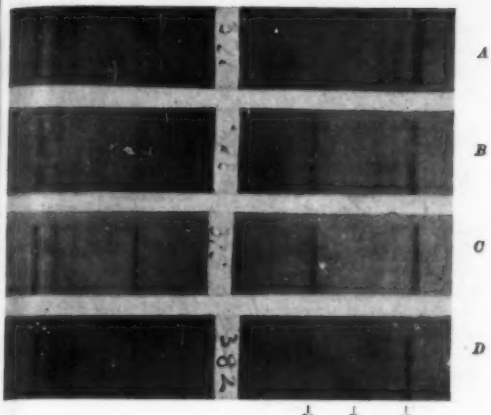
X-Ray Diffraction Effect Shown by some Specimens of Chrysotile

IN a study of the 'tailed' spots occurring on X-ray fibre photographs of chrysotile a camera with a slit approximately 0·7 cm. high was used, so that nearly 1 cm. of the fibre was irradiated. The purpose was to obtain lines instead of spots in the X-ray photograph, and thus facilitate photometry. The lines obtained, however, were beaded, the effect being particularly evident with specimens from Barberton (Figs. *A* and *B*). A specimen from Thetford showed only a slight variation in intensity along the lines (Fig. *C*), and a Russian specimen showed no visible variation. The effect can be imitated to some extent by pinching at regular intervals a specimen not showing it (Fig. *D*).

The beadiness seems to be due to a fairly regular variation of the scattering power along the fibres, possibly due to variation in external conditions during their growth. It is not due to multiple foci in the X-ray tube or irregularities in the slit system, since the beads move up and down with the specimen when its position is changed; they are not shown by all specimens, and are independent of the tube and camera used. It is unlikely that they are caused by non-uniform mechanical deformation of the fibres in detaching them from the lump, since they were shown by a specimen 0·10 cm. × 0·14 cm. in cross-section, which was quite rigid and could not bend to any extent during detachment.



(*A*) Specimen of chrysotile from Barberton, South Africa. (*B*) Another specimen from Barberton. (*C*) Specimen from Thetford, Canada. (*D*) Specimen *C*, pinched at intervals

We are grateful to Dr. F. A. Bannister, of the British Museum (Natural History), for verifying the existence of the beadiness with his apparatus, and to Dr. F. J. North, of the National Museum of Wales, for the gift of specimens. Part of the apparatus used was purchased with a grant from the Royal Society

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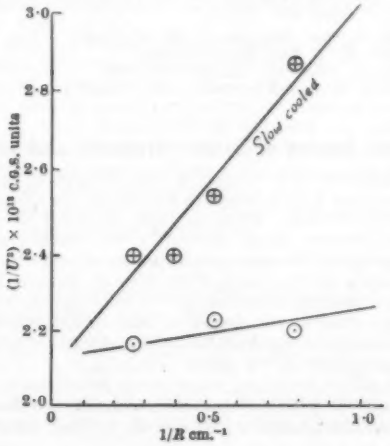
April 28.

Low-Order Detonation in Solid High Explosives

The recent communication[1] of Jones and Mitchell reporting the existence of a specific stable 'low' velocity of detonation in the case of crystalline or granulated T.N.T. is of considerable interest in that it emphasizes the importance of grain size in low-density unconfined charges. I have obtained similar results in the case of heavily confined cast T.N.T. charges, in which the grain size can be varied over fairly wide limits by variation in casting technique and alteration in the rate of charge cooling.



Velocities of detonation were measured over 30-cm. intervals by the Dautriche method with calibrated I.C.I. Cordtex as the standard detonant. Heavy copper confinement (3·2 gm./sq. cm. of charge surface) was employed, and measurements were made at a number of different charge diameters. The detonation velocities obtained with two widely different rates of charge cooling are summarized in the accompanying graph. It will be seen that plots of $1/U^2$ against $1/R$, where U is the observed velocity of detonation and R the charge radius, are approximately linear in character; but the slope of the line increases markedly with decreased cooling rate. The two experimental lines thus obtained are, of course, only two representatives of an infinite number possible between certain limits. These 'low' detonation velocities obtained by slow cooling were apparently stable in the sense that no change in velocity could be detected over 24 in. of charge length. The reduction in detonation velocity effected by slow cooling was very considerable, amounting to as much as 850 m./sec. at a charge diameter of 1 in., and cannot, therefore, be explained in terms of density changes, since these were very slight even at the slowest cooling rates.

Hydrodynamical calculations of detonation velocity assume that decomposition occurs at constant volume, under which condition it is dependent only on the heat of detonation and the density of the explosive. It has been known for some time, however, that in the case of solid high explosives, the detonation velocity normally decreases with decreasing charge radius. The best explanation of these detonation values lower than the hydrodynamic detonation velocity is on the basis of the lateral energy loss hypothesis of H. Jones[2]. In the case of solid high explosives, decomposition rarely occurs at constant volume since the process of chemical decomposition requires a very small but nevertheless finite time for completion. There is, therefore, behind the detonation front a region of finite length where equilibrium conditions have not yet been established, and which is usually termed the reaction zone. As a result of the very high pressures developed, some lateral expansion of the detonation products may occur in the region of the reaction zone, that is, before decomposition is complete, so that the maximum temperature and pressure are not developed. This will result in an energy decrease at the detonation front, with an attendant diminution in the velocity with which the detonation wave is propagated through the explosive.

The lateral energy losses will be a function of: (1) the charge radius; (2) the degree of confinement; (3) the 'reaction time' of the explosive, or the time required for the primary decomposition process, since this will determine the length of the reaction zone, and hence the time during which 'effective lateral expansion' can occur.

From the present series of experiments, in which considerable velocity changes have been produced at constant charge diameter and confinement by alteration in the rate of charge cooling, it would appear that the 'reaction time' of cast T.N.T. is a function of the rate of charge cooling. Since it is well established that the crystal size is very dependent on the rate of charge cooling, it seems very probable that the 'reaction time' of cast T.N.T. is a function of crystal size, increasing with increasing crystal size. The bearing of this crystal size – reaction time relationship on the mechanism of the detonative decomposition and the physico-chemical processes occurring in the

detonation wave will be discussed fully in a paper to be published shortly.

I acknowledge my thanks to the Chief Scientist, Ministry of Supply, for permission to publish this letter.

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April 17.

[1] Jones, E., and Mitchell, D., *Nature*, **161**, 98 (1948).
[2] Jones, H., *Proc. Roy. Soc.*, **A, 189**, 415 (1947).

Anomalous Magneto-Resistance Effects in Bismuth

The change of electrical resistance of bismuth in magnetic fields has been extensively studied, and the investigations of Kapitza[1] and subsequent workers on single crystals have led to the conclusion that the increase in resistance is proportional to the square of the field-strength in weak fields, becoming linear in strong fields. In the course of an investigation into the behaviour of thin fibres of bismuth, we have obtained results which indicate that in certain circumstances the resistance may undergo a small decrease at low field-strengths.

Fibres of bismuth in an envelope of soda glass may be prepared by hot-drawing and a wide variation in diameter is readily obtainable. The range in our experiments was about 5–150 μ. For various orientations of the magnetic field the resistance has been measured as a function of the angular displacement of the specimen. With the axis of rotation parallel to the specimen and perpendicular to the field, the resistance 'cycles' have a periodicity of π. A typical example is shown in Fig. 1.

Comparison of such results with those obtained for single crystals[2] leads to the conclusion that, in general, the fibres are single crystals with the main cleavage plane parallel to the axis.

For a given orientation, the resistance may be plotted against field-strength. In the case of certain fibres the curve so obtained is anomalous in that the change of resistance is negative for a certain range of field strength. The effect is illustrated in Fig. 2, which was obtained with a fibre orientation corresponding to the minimum of Fig. 1.

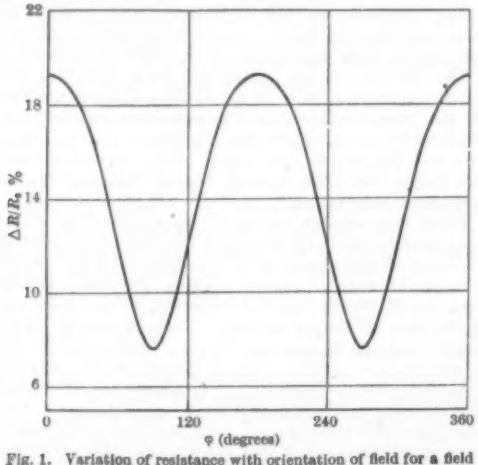

Fig. 1. Variation of resistance with orientation of field for a field of 6,300 oersteds (R_0 = 42 ohms)

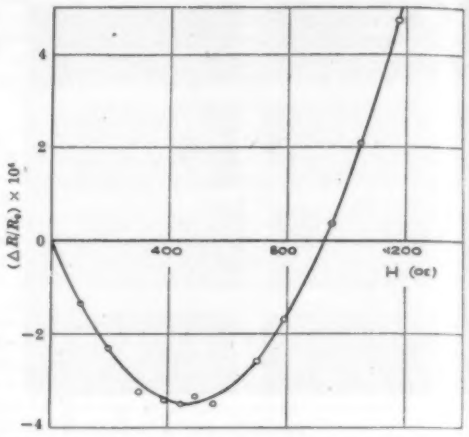

Fig. 2. Dependence of resistance on field-strength, illustrating the negative change

The anomalous change is quite small, and it will be seen that at the minimum of Fig. 2 it is of the order of 4 parts in 10^4. At first sight, a possible interpretation would appear to be in terms of a Hall E.M.F.; but the form of the specimens makes this unlikely and, moreover, the phenomenon does not appear with all fibres.

A negative change in resistance has been predicted on theoretical grounds by Meixner[3] for certain relative orientations of current, field and crystal axis. No previous experimental evidence is known to us, with the possible exception of a paper by Casimir and Gerritsen[4]. The latter, however, attribute their apparent *Umkehreffekt*, obtained with a single crystal, to the presence of a Hall E.M.F. In the case of our specimens, it would seem that while the direction of the current is normally parallel to the main cleavage plane, cases sometimes occur in which this is no longer the case.

A more detailed discussion will be presented elsewhere.

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April 20.

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Excited States of Silver Bromide and Iodide

It appears that study of the absorption spectra of the silver halide vapours has, with the exception[1] of silver chloride, hitherto been confined to wavelengths above about 2500 A. We have recently photographed the absorption spectra of silver bromide and iodide in the range 2150–3000 A. with a Hilger medium quartz instrument. Within rather critical pressure limits, red-degraded absorption bands are observed in the region 2150–2475 A. for silver bromide and 2150–2350 A. for silver iodide.

For silver bromide, some forty bands have been assigned to a single system involving a transition between the ground-state[2] and an excited state with

constants $\nu_e = 43{,}537{\cdot}4$, $\omega_e = 205{\cdot}0$, $x_e\omega_e = 0{\cdot}74$ cm.$^{-1}$. The vibrational constants refer to $^{109}Ag^{81}Br$.

In the spectrum of silver iodide in this region, there appear to be two partly overlapping systems, resulting from transitions from the ground-state to two excited states:

C. $\nu_e = 44{,}717{\cdot}7$, $\omega_e = 158{\cdot}1$, $x_e\omega_e = 2{\cdot}3$ (for ^{107}AgI),
D. $\nu_e \sim 46{,}000$, $\omega_e \sim 165$ cm.$^{-1}$.

Thirty bands have been assigned to system $C \leftarrow N$, 17 to $D \leftarrow N$.

The products of dissociation cannot be determined unambiguously; but the most likely products are $Ag(^2P)$ plus halogen (^2P) for all three excited levels.

The relations between the states of the silver halides are summarized below, where k_e is the force-constant in dyne/cm. $\times 10^{-5}$, and ν_e is the system-origin in electron-volts. There seems to be little doubt that the new levels are analogous to the levels *C* and *D* of silver chloride.

State		AgCl	AgBr	AgI
D	ν_e	6·05	—	5·7
	k_e	1·3$_2$	—	0·9$_9$
C	ν_e	5·40	5·40	5·54
	k_e	1·318	1·149	0·85
B	ν_e	3·92	3·88	3·87
	k_e	1·226	0·894	0·521[3]
N	ν_e	0	0	0
	k_e	1·832	1·678	1·453

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The 'Renal Threshold'

According to the definition of Barclay *et al.*[1], the 'renal threshold' can be expressed as a rate of tubular reabsorption per 100 c.c. glomerular filtrate. Thus

$$T = 100\,\frac{Rx}{C}, \qquad (1)$$

where T is 'threshold', Rx is the amount of the 'threshold substance' reabsorbed by the tubules (mgm./min.), and C is clearance of inulin, or mannitol. The same conception of the 'threshold' is also used by Harrison *et al.*[2].

In 1945 I published with Szenes[3] a paper entitled "Aglucosuric Blood Sugar Concentration"[3,4]; this is a calculated blood sugar concentration, above which filtered glucose is not reabsorbed, but passes into the urine. This concentration is thus a dynamic 'threshold'; and the formula can, of course, be used not only in the case of glucose, but also in the case of any other 'threshold substance'.

We deduced the formula of such a threshold substance concentration as follows:

$$Ex = Fx - Rx, \qquad (2)$$

where Ex is excreted substance (mgm./min.), Fx is filtered substance (mgm./min.).

But $Ex = \frac{V.Ux}{100}$; $Fx = \frac{C.Px}{100}$; $Rx = \frac{C.Ax}{100}$;

where V is urine (c.c./min.), Ux is concentration of substance in urine (mgm. per cent), C is clearance of inulin, Px is concentration of substance in blood (mgm. per cent), and Ax is threshold (Szenes and Földi's formula).

So $V.Ux = C.Px - C.Ax$; $Ax = Px - \frac{V.Ux}{C}$;

but $C = \frac{U.V}{P}$,

where U and P are urinary and plasma inulin concentration (mgm. per cent) respectively.

Hence $Ax = Px - \frac{P}{U}\,Ux.$ (3)

The purpose of the present note is to determine the relation of our formula to Barclay's 'threshold'.

As I have pointed out above, Barclay's formula is:

$$T = 100\,\frac{Rx}{C}.$$

From equation (2):

$$Rx = Fx - Ex.$$

Hence $T = \frac{Fx - Ex}{C} \cdot 100 = \frac{C.Px - V.Ux}{C} =$

$$Px - \frac{V.Ux}{C} = Px - \frac{P}{U} \cdot Ux.$$

Thus Barclay's 'threshold' and our formula are identical. This is noteworthy because we have deduced our formula by means of mathematical considerations, while Barclay chose his definition of the threshold because "plasma values are usually expressed to 100 c.c. and . . . 100 c.c. would appear to be fairly close to the more recent determination of the average rate of filtration in man".

From the equations

$$Rx = \frac{C.Ax}{100} \text{ and } Fx = \frac{C.Px}{100},$$

we have $\frac{Rx}{Fx} = \frac{Ax}{Px}$,

whence $Ax = Px \cdot \frac{Rx}{Fx}.$ (4)

This equation shows that the calculated concentration of the threshold substance in the blood is a function of the actual concentration, the rate of tubular reabsorption and glomerular filtration.

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April 12.

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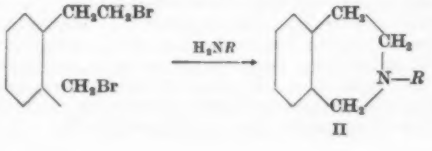
[2] Harrison and Harrison, *Amer. J. Physiol.*, **134**, 78 (1941).
[3] Szenes and Földi, *Orvosok Lapja*, **3** (1945, in Hungarian).
[4] Földi, Szabó and Zsoldos, *Experientia*, **3**, 8 (1947).

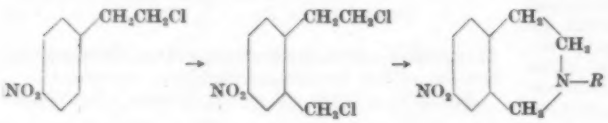
A New Synthesis of 2 : 7-Disubstituted-1 : 2 : 3 : 4-tetrahydro-*iso*-quinolines

It has been shown by Holliman and Mann[1] that *o*-2-bromoethyl-benzyl bromide (I) condenses readily with primary amines to give 2-substituted-1 : 2 : 3 : 4-tetrahydro-*iso*-quinolines (II). Although hitherto



II

this has apparently been the only known method for the synthesis of 2-aryl-*iso*-quinolines of type (II), it has one serious disadvantage, namely, that for various reasons it does not lend itself to the preparation of *iso*-quinolines of this type having substituent groups in the benzene ring. The presence of such groups may be essential if the tetrahydro-*iso*-quinoline is to possess marked physiological action. To overcome this difficulty we have developed the following synthesis.



III IV V

2-Phenyl-ethyl chloride on nitration affords *p*-nitrophenyl-ethyl chloride[2] (III), which we find undergoes ready chloromethylation to the crystalline 5-nitro-2(2-chloroethyl)-benzyl chloride (IV). We have condensed this compound with several primary amines to obtain in each case the corresponding 7-nitro-2-aryl-1 : 2 : 3 : 4-tetrahydro-*iso*-quinoline (V). These *iso*-quinolines have in turn been converted to their 7-amino, 7-acetamido and other derivatives. The preparation of the dichloride (IV) is much simpler than that of the dibromide (I), and thus affords a ready route to these 7-substituted-*iso*-quinoline derivatives.

2-Phenyl-ethyl bromide can be similarly nitrated and then bromomethylated to form 5-nitro-2(2-bromoethyl)-benzyl bromide, which also readily gives the above cyclization with primary amines.

We are now investigating the synthesis of the phosphorus and arsenic analogues of compounds of type (V).

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Tryptochrome: a Pigment Derived from Tryptophan

When 5 ml. of a very dilute (*c.* 0·05 per cent) solution of tryptophan in 60–80 per cent acetic acid is treated with a drop of 1 per cent aqueous potassium iodate, and warmed to boiling, a violet-pink colour develops, and an intense greenish-orange fluorescence. On dilution with two volumes of water, the pigment gradually separates, and can be extracted with *iso*butyl alcohol or with chloroform, in which solvent it shows a strong absorption band at λ 565–555 mμ, and a weak band at λ 520–515 mμ. Pigment formation requires a large excess of acetic acid, otherwise the mixture turns brown, and an iodotryptophan is precipitated, from which the pigment cannot be generated. The pigment is stable in acid solution, and both tint and fluorescence survive exposure to air and light for months.

The iodate can be replaced by hypochlorite bromate, or free bromine; but the pigment is less pure, and is very easily destroyed by a slight excess of the reagent. Chlorate, peroxide, persulphate, perborate, manganese dioxide, ferricyanide and ferric iron are ineffective for colour production.

The name 'tryptochrome' is suggested for the pigment, since it closely resembles, and may be identical with, the pigment formed in the well-known protein-ochrome reaction, obtained when tryptophan or a trypsin digest of protein is treated with bromine water, and extracted with amyl alcohol. The tryptochrome test will show free tryptophan in dilutions down to about 1 in 100,000. None of the other common amino-acids gives the reaction. On prolonged boiling with sufficient iodate, indole forms a mixture of pigments, including what appear to be indirubin and isatin; but the conditions are much more drastic than those required for tryptochrome, and persulphate is more effective than iodate. Addition of iodate to a faintly acid solution of adrenaline leads to formation at room temperature of an iodoadrenochrome[1]. Under such conditions, tryptophan gives no colour. Adrenochrome closely resembles tryptochrome in tint, but neither it nor indirubin shows the orange fluorescence characteristic of tryptochrome.

Structure of tryptochrome. (1) Analysis of the product crystallized from a mixture of chloroform and light petroleum gives the percentage composition: C, 69·9; H, 4·6; N, 13·9, corresponding to the formula $C_{17}H_{14}O_2N_2$. (2) The reaction requires the free α-amino-group of the tryptophan. It is not given by unhydrolysed proteins, or by β-indolepropionic acid, or by tryptophan after treatment with nitrous acid or formaldehyde. (3) The reaction requires an unsubstituted α-carbon in the pyrrole ring. (4) Reduction in acetic acid by magnesium or zinc yields a leuco-product that gives no catechol reaction with molybdate or phenolic reaction with iron. The leuco-product slowly reoxidizes to tryptochrome on aeration. Hence it is concluded that tryptochrome, unlike adrenochrome, is not a quinone.

The evidence now obtained suggests that tryptochrome is an indirubinoid derivative.

The preparation and properties of tryptochrome are being investigated in the Chemical Department of this University by Mr. W. A. Boggust, aided by a grant from the Medical Research Council of Ireland. I am very grateful to Prof. Wesley Cocker for these facilities and for the interest he has taken in the work.

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April 20.

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Alkaline Phosphatase and Tumour Inhibition

In the course of bioassays of extracts of normal male urine[1,2] for tumour-inhibiting properties, we have investigated their effect on alkaline phosphatase present in certain tumours by Gomori's histological technique. Similar examinations were carried out using other tumour-inhibitory substances, namely, stilbœstrol[3] and colchicine[4,5].

For the purpose of denoting the quantity of alkaline phosphatase in the tissues under investigation, we have used mouse kidney tissue as a comparative standard. All tissues, treated and untreated tumours and kidney, were incubated in the same jar and their further treatment carried out under identical condi-

tions. Inbred albino mice were used as experimental animals.

(1) *Tumours investigated.* Transplants of Twort-mammary carcinoma, sarcoma and carcinoma induced by subcutaneous inoculation of crystallized methylcholanthrene, a transplant from the induced carcinoma, spontaneous mammary carcinoma in mice and their transplant. The Twort-mammary carcinoma shows a high concentration of alkaline phosphatase, so also do the transplants of the spontaneous mammary carcinoma in the first generation, but to a lesser degree. The other tumours referred to above contained little or no demonstrable alkaline phosphatase.

For the purpose of continuing our investigation Twort-mammary carcinoma were used.

(2) *Tumour-inhibiting substances.* (*a*) Toluene extract of urine and certain fractions thereof (possibly related to *H* 11), single dose 0·8 or 1·6 mgm. (*b*) Stilbœstrol, single dose 0·25 mgm. (*a*) and (*b*) were dissolved in 0·05 ml. of arachis oil and injected intraperitoneally twice a day on seven consecutive days. (*c*) Colchicine, 0·02 mgm. in 0·2 ml. of water, the mitoses arresting dose[5], given subcutaneously twice a day on three or five consecutive days. Mice were dissected when their body temperature dropped to 32·8° C. or less.

Untreated tumour-bearers or mice treated with arachis oil were used as controls.

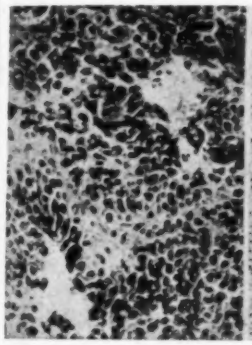

Fig. 1. × 200

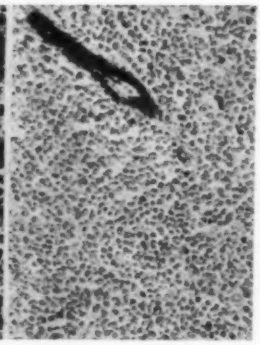

Fig. 2. × 200

Results. (*a*) Urinary extracts: a marked diminution and, in some cases, almost a complete absence of alkaline phosphatase even in highly cellular portions of the tumours. The accompanying photomicrographs of control and treated tumours of approximately the same growth-rate and cellularity show these differences (Fig. 1, injected with arachis oil, 63 sq. mm.; Fig. 2, treated with extract, 60 sq. mm. surface area). It was our experience, however, that the amount of alkaline phosphatase demonstrable was approximately inversely proportional to the degree of inhibition of growth.

(*b*) Stilbœstrol: no diminution, but perhaps an increase in alkaline phosphatase. The adrenals of the treated mice, when compared to the controls, show a marked deposit of alkaline phosphatase in the subcapsular layers of the zona glomerulosa. This appearance may be of interest as it is claimed that regeneration of the adrenocortical cells commences in this area.

(*c*) Colchicine: alkaline phosphatase diminution due to cellular degeneration of tumours.

The cellular or other structure of each tumour was checked by hæmatoxylin-eosin staining of alternate sections.

It would appear that growth inhibitors present in normal male urine directly or indirectly reduce the alkaline phosphatase content of certain tumour cells.

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Effect of Sputum on Streptomycin

In a small series of seventeen cases of whooping cough treated with streptomycin, no beneficial effects were noted. The children receiving parenteral therapy, five hours after injection, had blood-levels of 2–12 units per ml. It was not possible to detect streptomycin in the blood of thirteen patients receiving aerosal therapy after 15, 30, 60 min. or 3 hr. The urine of these patients at no time during 24 hr. showed the presence of streptomycin.

Because of the inability to recover streptomycin after inhalation, *in vitro* tests were devised to observe the behaviour of streptomycin in the presence of lung extract, lung tissue, mucin and gastric juice; the sources of these substances were sputum, 6 gm. of guinea pig lung ground in 10 c.c. nutrient broth, 10 per cent potassium hyaluronate and human resting-gastric juice, respectively.

Using the streptomycin assay technique devised by Mitchison, clear-cut results were obtained. The 10-mm. column of assay agar containing *Staph. mayo* was layered with the test material and the zone of growth inhibition of staphylococci was measured.

The mucin of the gastric juice, in contrast to the lung extract, potassium hyaluronate and sputum, allowed full activity of the streptomycin. Sputum was either shaken with streptomycin in a bottle containing glass beads before it was layered on a column of assay agar, or the sputum was layered on the medium and the streptomycin inoculated on top of the sputum. The potassium hyaluronate was shaken with streptomycin before being transferred into the assay tube.

By plotting the zone of growth inhibition in mm. against the logarithm of a known concentration of 2, 3, 4, 5, 10, 50 units streptomycin per ml., a graph was obtained from which the streptomycin content of inoculated material could be read. When layered on to the agar, before incubation, all mixtures were known to have a final concentration of 5 units streptomycin per ml. After 18-hr. incubation these mixtures were shown to contain less than one unit per ml.

Table 1 represents two experiments. The mean in mm. of inhibition and standard deviation of ten tubes for each group is recorded. Table 2 represents the mean and standard deviation of six tubes which were layered with sputum collected from a patient at 0, 3, 6, 9 hr. after having received an intramuscular injection of 1 gm. streptomycin. (Patient's blood

Table 1. Mean and standard deviation of zone of inhibition produced by :

	Sputum shaken with strepto-mycin	Sputum layered on agar, strepto-mycin super-imposed	Potassium hyalur-onate shaken with strepto-mycin	Strepto-mycin (10 units/ ml.)	Strepto-mycin (5 units/ ml.)
Exp. 1	2·1±0·21	0·5±0·71	2·38±0·37	6·0±0·16	4·7±0·27
Exp. 2	2·9±0·48	0·1±0·32			4·9±0·05

Table 2. Mean and standard deviation of zone of inhibition induced by sputum, before and after parenteral streptomycin

Hours	0	3	6	9	Control, strepto-mycin 5 units/ml.
	0·5±0·71	0·4±0·44	0·6±0·52	0·6±0·52	4·9±0·05

5 hr. after receiving the streptomycin contained 7 units per ml.)

The differences between the three left-hand groups of Table 1 and either of the two right-hand groups, and the difference between the experimental groups and the control in Table 2 would have happened by chance much less than once in a thousand trials. This means that the difference between the means is highly significant.

The sputum, which was found to be alkaline, prevented the action of streptomycin either by a mechanical inhibitory action, or by a chemical inactivation, but not as a result of an acid reaction.

This observation helps to explain why organisms normally sensitive to streptomycin fail to be affected when embedded in sputum. The unsuccessful streptomycin trial in whooping cough may possibly be explained in this way. The disappointing results in the treatment of pulmonary tuberculosis can be understood, for on this basis tubercle bacilli, lying in sputum which has rendered the antibiotic sublethal, multiply and become resistant. The tubercle bacilli free in the spinal cord are destroyed, whereas those embedded in exudate at the base of the brain survive. When the tubercle bacilli lie on surface lesions such as ulcers of the larynx or vocal cords, the response to treatment is dramatic; but open phthisis is proving resistant to treatment.

Thanks are due to the Non-tuberculosis Streptomycin Trials Committee for the streptomycin and to Dr. B. Woolf and Miss E. Duncan for the statistical assay.

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Reconstruction of Laccase from its Protein and Copper

The conception that oxidases are metallo-protein compounds in which the metal plays an essential part in the catalytic activity of the enzyme was introduced by Gabriel Bertrand[1] in the course of his studies on laccase, the oxidizing enzyme present in the latex of the Indo-Chinese lacquer tree. As crude preparations of laccase contained an appreciable amount of manganese, Bertrand assumed that this metal forms the active part of the oxidase. A more recent study of this problem by Keilin and Mann[2], based upon highly purified enzyme prepared on a large scale from the latex of different lacquer trees, produced evidence that the active metal is not manganese but copper. This view, however, was challenged by Didier Bertrand[3], who claimed to have isolated an enzyme of higher activity which contained 0·15 per cent manganese and only 0·014 per cent copper.

While studying the properties of laccase, an attempt was made to split the enzyme into its two constituent parts and to reconstruct it from its protein and a metal. The method used was that devised by Kubowitz[4] in the course of his study on the polyphenol oxidase of potato. The experiments were carried out as follows :

(1) The activity of the enzyme was tested in the Barcroft manometers. The following system was used : 10 mgm. pyrocatechol or hydroquinone, a suitable amount of laccase preparation, 0·1 *M* phosphate buffer *p*H 6·7 to a final volume of 3·3 ml. The manometer was shaken at about 160 cycles per min. and readings were made for the first six minutes.

(2) Enzyme preparations of activity (Q_{O_2}) varying from 3,000 to 18,000 in presence of pyrocatechol were obtained from the latex of the Indo-Chinese lacquer tree (*Rhus succedanea*) by fractional precipitations with alcohol and ammonium sulphate and by further purification with tricalcium phosphate gel.

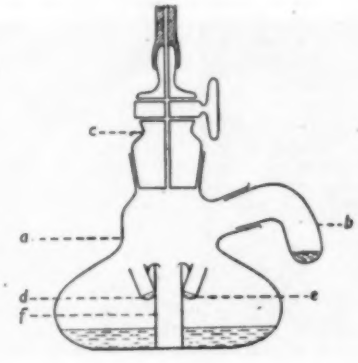

Fig. 1

(3) The splitting of the enzyme was performed in a modified flask of the Barcroft differential manometer (see Fig. 1). The flask (*a*) of about 30 ml. capacity has a side bulb (*b*) with a ground joint so that the contents of the bulb can easily be run into the flask by giving it a half-turn. The flask is provided with a stopper and tap (*c*) which can be connected with a vacuum pump and to a source of pure nitrogen. Two small dangling tubes (*d* and *e*) are suspended by means of platinum hooks from the lip of the central tube (*f*) fused to the bottom of the flask.

4 ml. of either crude or purified concentrated enzyme preparation and 1 ml. 0·5 *M* phosphate buffer *p*H 7·0 are placed in the flask *a*. The dangling tubes *d* and *e* receive 2 mgm. catechol and 3·2 mgm. ascorbic acid respectively and the side bulb *b* receives 0·03–0·05 ml. 2 *M* potassium cyanide in 0·05 *N* potassium hydroxide. After evacuating the flask and filling it with pure nitrogen, catechol and ascorbic acid are added to the enzyme by dislodging the dangling tubes, and then cyanide is added from the side bulb.

The mixture is left standing for 30 min. at room temperature. The flask is then opened and its contents are cooled to 0° C. and saturated with solid ammonium sulphate. The precipitated enzyme is centrifuged off and washed with 50 ml. of saturated ammonium sulphate containing 0·02 *M* potassium cyanide. The precipitate is dissolved in the minimum amount of water and dialysed for 12 hr. at 0° C. against 3 l. of 0·01 *M* phosphate buffer *p*H 7 and for a further 36 hours against 3 l. 0·005 *M* phosphate, which is changed three times.

The enzyme preparation thus obtained has almost completely lost its catalytic activity in the oxidation of catechol or hydroquinone.

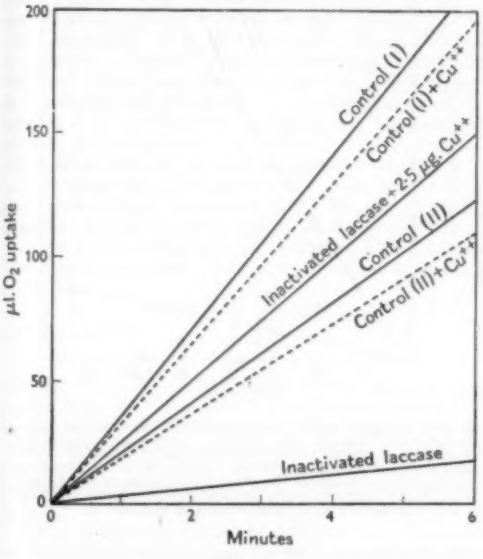

Fig. 2

(4) For the reactivation of this enzyme preparation, 2·5–12 μgm. of cupric, ferric or manganese ions are added (as cupric and ferric sulphates or manganese chloride) to 2 ml. samples of the inactivated enzyme preparation and left standing at room temperature for periods varying from 30 min. to 3 hr. The catalytic activities of these samples were then tested and compared with those of the untreated control samples (I) estimated at the beginning of the experiments, the control samples (II) treated only with ammonium sulphate and dialysed, and the samples inactivated by cyanide treatment. These experiments show that the activity of the cyanide-treated samples of laccase was not affected by the addition of either ferric or manganese ions, but was markedly increased by the addition of very small quantities of cupric ions. Fig. 2, which summarizes the results of the experiments with cupric ions, shows that the addition of 2·5 μgm. of this metal to the inactivated enzyme raised its activity to a level occupying an intermediate position between the controls I and II. That the activity of this reconstructed enzyme is somewhat higher than that of the control II is probably due to the fact that cyanide protected the protein of the inactivated enzyme from slow but irreversible changes which were proceeding in the control preparation II when it was submitted to precipitation and dialysis. It is important to note that the small concentration of cupric ions which strongly activated the cyanide-treated enzyme had no catalytic effect on the oxidation of either catechol or hydroquinone, and when added to the control enzyme preparations slightly inhibited their activities (Fig. 2).

These experiments clearly demonstrate that laccase is a copper-protein enzyme.

My thanks are due to Prof. D. Keilin, for his help and advice.

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Localization of Polyphenoloxidase in the Chloroplasts of *Beta vulgaris*

The chloroplast as the seat of chlorophyll pigments in plants occupies a unique position in the economy of the green cell. In recent years there has been a renewed interest in the reactions and properties of chloroplasts as a result of the work of Hill[1,2] and Hill and Scarisbrick[3,4], who demonstrated that the reaction characteristic of photosynthesis in green plants, the evolution of oxygen, occurs in appreciable quantities in isolated chloroplasts under the influence of light and in the presence of suitable oxidants.

In the course of an investigation of oxygen evolution by isolated chloroplasts, it was deemed important to explore their enzymatic composition. Of special interest were considered enzymes capable of participating in oxidation-reduction reactions and, more particularly, those localized principally, if not entirely, in the chloroplasts. This communication presents evidence that a copper enzyme, polyphenoloxidase (otherwise known as tyrosinase or catecholase), is localized in the chloroplasts of spinach beet (chard), *Beta vulgaris*.

In a preliminary experiment, it was found that the addition of catechol to a crude leaf extract of spinach beet leaves was followed by a rapid uptake of oxygen. This suggested the presence of a polyphenoloxidase in the leaves, and it became of interest to determine whether the enzyme is found in the chloroplasts or in the cytoplasmic fluid obtained after the separation of chloroplasts and their fragments.

Leaves of plants grown in sand cultures were mashed in a Waring blender and the green extract fractionated by high-speed centrifugation (approximately 25,000 *g*) into a suspension of chloroplast fragments and a 'cytoplasmic fluid' practically free of chlorophyll.

Polyphenoloxidase activity of the two fractions was tested by using catalytic amounts of catechol with ascorbic acid as a substrate[6]. Consistent with the well-established[6,7] copper-protein nature of polyphenoloxidase, the activity of this enzyme in the chloroplasts was inhibited with cyanide and carbon monoxide. The carbon monoxide inhibition was insensitive to light[6]. The enzyme was also inhibited by more specific copper poisons such as sodium diethyldithiocarbamate[6].

The procedures used for disintegrating leaves were necessarily drastic and resulted in disruption of

cytoplasmic bodies, including the chloroplasts. The possibility was therefore considered that the localization of polyphenoloxidase activity in the chloroplasts could be attributed to preparatory technique. On *a priori* grounds this was considered unlikely: the enzyme persisted in the chloroplast fragments and was absent from the cytoplasmic fluid, into which it would be expected to pass in case of disruption of the chloroplasts. Nevertheless, experiments were carried out with the experimental procedures modified in several respects, giving special attention to differences in technique which might have accounted for such divergent reports as were found in the literature.

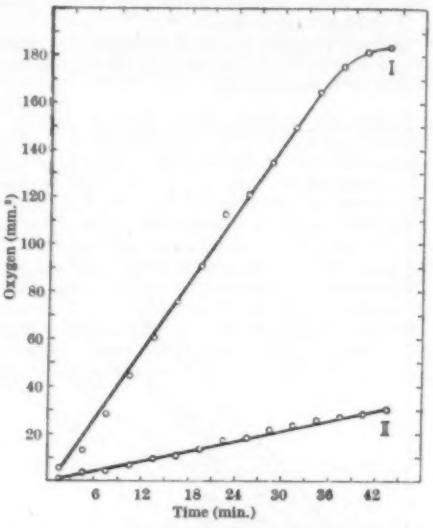
First, the possibility was considered that if the enzyme were originally present in the cytoplasmic fluid, then the high-speed centrifugation used for separating the chloroplast fragments might have sedimented the enzyme as well. This point was tested by adding a crude potato polyphenoloxidase to the leaf mash prior to the high-speed centrifugation. Upon subsequent fractionation of the mash into chloroplast fragments and cytoplasmic fluid, the added potato polyphenoloxidase was recovered in the cytoplasmic fluid. The polyphenoloxidase activity of the chloroplast suspension was not enhanced.

Warburg and Lüttgens[9], working with similar preparations from spinach and sugar beets, attributed about a quarter of the polyphenoloxidase activity of the crude green leaf extract made at *p*H 6·5 to chloroplast suspensions and the remaining three-quarters to the cytoplasmic fluid. These authors considered the *p*H of the extract important. At an acid reaction, at *p*H 5 for example, they found that a major portion of the cytoplasmic polyphenoloxidase was precipitated and in a subsequent centrifugation was recovered with the chloroplast fragments.

Although the preparations used in this investigation were uniformly made at *p*H 6·5, it was undertaken to test the effect of hydrogen ion concentration on the distribution of polyphenoloxidase by extracting the chloroplast suspension at the more alkaline *p*H 7·3. The results indicated that, as with other preparations, the polyphenoloxidase activity of leaf extracts made at *p*H 7·3 was also localized in the chloroplasts.

Bonner and Wildman[10] studied the respiration of spinach leaves and concluded that polyphenoloxidase is their terminal oxidase. Unlike the present findings, however, these authors reported the presence of polyphenoloxidase as confined to the cytoplasm rather than to the chloroplasts. The technique used by Wildman and Bonner[11] involved grinding the chloroplasts in a Charlotte colloid mill, with resultant disintegration of chloroplasts into chlorophyll-containing granules and non-chlorophyllous 'stroma'. These authors[11] are aware that their conclusions as to the distribution of enzymes between chloroplasts and cytoplasm can be properly interpreted only with reference to their own manipulative technique. It was already noted that in the same plant, spinach, Warburg and Lüttgens[9] found polyphenoloxidase both in chloroplast fragments and in cytoplasm. The spinach beet used in the present investigation is a chenopodiaceous plant related to sugar beet and spinach.

It seemed desirable, in view of the results of Bonner and Wildman[10], to subject the already disrupted chloroplasts comprising the chloroplast suspensions used in this investigation to further disintegration. This was done by grinding the green leaf extracts with glass beads for 10 min. in a Mickle tissue-disintegrating machine, prior to the high-speed centrifugation. A microscopic examination of the ground chloroplast suspension disclosed uniform round particles more than 1 millimicron in diameter. This further subdivision of the chloroplast fragments failed to dislodge the polyphenoloxidase. As before, the enzyme was found in the chloroplast suspension rather than in the cytoplasmic fluid. The results are presented in the accompanying graph.



Polyphenoloxidase activity of chloroplast fragments and cytoplasmic fluid of spinach beet. Curve I: disintegrated chloroplast suspension containing 0·8 mgm. of chlorophyll. Curve II: cytoplasmic fluid containing 0·02 mgm. chlorophyll, after removal of disintegrated chloroplasts. Reaction mixture contained 2·4 mgm. ascorbic acid and 0·02 mgm. catechol in *M*/15 potassium phosphate buffer (*p*H 6·5). Temperature of bath, 20° C.

The localization of a copper-protein oxidase in cellular bodies so intimately identified with the process of photosynthesis raises at once the question of the possible participation of this enzyme, directly or indirectly, with one or more of the biochemical reactions which are linked with the process of photosynthesis in those green plants which contain polyphenoloxidase[12]. The answer to this question must await further experimentation.

A full account of these experiments will be published elsewhere.

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DEFINITIONS OF BOND-ENERGY IN PHYSICAL CHEMISTRY

THE expression 'bond-energy' continues to be used in at least two senses: (*a*) for the *mean* contribution from each bond of a given type to the total heat, $-\Delta H$, of formation of the molecule from its constituent atoms; (*b*) for the energy, ΔH, required to disrupt the molecule at a particular bond into two fragments.

As was first pointed out by Fajans[1], and later developed by Sidgwick and Pauling, the 'bond-energy', usage (*a*), of a given bond $X—Y$, shows a remarkable degree of constancy over a wide range of compounds, provided that the valency of neither X nor Y alters. But the 'bond-energy', usage (*b*), may vary markedly with the molecular environment of the bond. Despite frequent warnings[2], confusion between these two interpretations of 'bond-energy' still exists, and it seems to us desirable that the simple but ambiguous expression 'bond-energy' should be abandoned in favour of two separate expressions specific for the usages (*a*) and (*b*).

For usage (*a*), the expression 'mean bond-energy term' has already been proposed[3]. We would further suggest the use of the symbol $E(X—Y)$ to denote this quantity. The relation between $E(X—Y)$ and the thermochemical data for a molecule XY_n is given by

$$n\,E(X—Y) = -\Delta H_{298}$$

for the reaction

$$X_{(g)} + nY_{(g)} \rightarrow XY_{n(g)},$$

that is, the heat of formation of the gaseous compound from the free atoms of its constituent elements, the 'atomic heat of formation'. We suggest the use of a superscript a in discussing enthalpy terms for reactions in which the initial state of the system is that of free atoms, and we follow Bichowsky and Rossini[4] in using Q for $(-\Delta H_{298})$. The particular $-\Delta H_{298}$ term in question, above, has then the symbol $Qf^a_{(g)}$, which, if considered too cumbersome, might be modified to Q_a. For the heat of formation of the gaseous compound from its elements *in their standard states*, we suggest the symbol $Qf^s_{(g)}$, while for the $-\Delta H_{298}$ for the formation reaction in which both the set of initial elements and the final compound are all in their standard states, the symbol Qf° follows from the universally accepted convention of Lewis and Randall[5].

For the usage (*b*), we would suggest the expression 'bond dissociation energy' and the symbol D together with a specification of the particular bond; for example, $D(XY_{n-1}—Y)$. In the case of polyatomic molecules there is not necessarily an identity between the quantities $E(X—Y)$ and the individual $D(X—Y)$ values, the only connexion being that, for a given molecule, the sum of all the E terms shall equal the sum of the D values for each stage in the stepwise dissociation of the molecule into free atoms.

In constructing tables of mean bond-energy terms, Sidgwick and Pauling adopted the convention of measuring the atomic heats of formation with respect to ground-state atoms. Recently, Long and Norrish[6] have expressed the view that in dealing with compounds of tetravalent carbon, the E values for carbon bonds should be assessed, not from the $s^2p^2\ ^3P$ ground-state but from the $sp^3\ ^5S$ excited state. They urge this on the grounds that molecules such as CH_4 (for example) are built up from the tetravalent ^5S carbon atom and not from the divalent ^3P ground-state. This change in the zero from which the total energy content is to be measured should be correspondingly reflected in the symbols used; for example, by using Qf^{a*} in place of Qf^a, and E^* in place of E. In this connexion we are unable to agree with the statement of Long and Norrish[6b] that Pauling's table of mean bond-energy terms "contains values deficient in the case of links involving carbon", for Pauling's E values are no less true in respect of his definition of a mean bond-energy term than are the E^* values of Long and Norrish, which are based on a different definition.

If one adopts consistently the point of view that in the specific case of tetravalent carbon compounds E^* terms are preferable to, or more significant than, E terms (because of the building up of such compounds from $C(^5S)$), one must recognize the necessity of discarding E terms in favour of E^* terms for a large number of bonds other than those involving carbon. An example is provided by the beryllium hydride molecule BeH, which, although dissociating to give a ground-state ^1S beryllium atom, would be considered as built up from the excited ^3P state; similarly with the sodium chloride molecule NaCl, since this 'derives' essentially from the ion-pair $Na^+\ Cl^-$, despite its dissociation into ground-state atoms. These two examples are relatively simple ones; in others, for example, hydrogen fluoride, HF, it is rather difficult to identify the atomic species from which the molecule is built up. In general, it seems to us that the Pauling convention leads to mean bond-energy terms in a more simple and less ambiguous manner than would result from a consistent application to all compounds of the convention used by Long and Norrish in respect of carbon compounds.

In connexion with their view that, in tetravalent carbon compounds, E^* values are more significant than E values, Long and Norrish make the specific point that it is reasonable to correlate E^* (C—H) in CH_4 with $D(CH_3—H)$, whereas a correlation with E (C—H) would be meaningless. They develop from this point an attack on the problem of deciding between the two spectroscopically permissible values for 'L_1', the ΔH_0 for the reaction

$$C_{\text{graphite}} \rightarrow C(^3P)_{(g)}.$$

Their numerical correlation of E^* (C—H) in CH_4 with $D(CH_3—H)$ leads them to conclude that $(L_1 + x) \sim 190$ kcal./gm. atom, where x is the excitation energy, ΔH_0, for the atomic transition $C(s^2p^2,\ ^3P) \rightarrow C(sp^3\ ^5S)$. Recently, Shenstone[7], by experimental observation, has given the value of x as 96·4 kcal./gm. atom. This throws some doubt on the assessment of $(L_1 + x) \sim 190$ kcal., since such a value would imply that L_1 is less than 100 kcal. The assessment of $(L_1 + x) \sim 190$ kcal. is based on two assumptions: (i) that the bonds in the $\cdot CH_3$ radical are roughly equivalent in strength to those in CH_4 (that is, the 'energy of reorganisation' of the $\cdot CH_3$ radical is small), and (ii) that the tetracovalent state of the carbon atom in CH_4 is identical with the ^5S state of the free carbon. But, with regard to (i), since we cannot either describe with certainty the character of the C—H bonds in the $\cdot CH_3$ radical (sp^3 or sp^2 bonding ?), or make due allowance for the interaction between non-bonded hydrogen atoms in $\cdot CH_3$ or CH_4, the reorganisation energy cannot be simply estimated, and might be quite different from the value chosen by Long and Norrish; and in respect of (ii) Van Vleck[8], in a detailed discussion of

this specific point in 1934, concluded that the 'valence-state' cannot be identified with any one of the six atomic states of the carbon atom corresponding to the configuration sp^3, but is rather to be considered as a linear combination of all six levels (Van Vleck computed that the 'valence-state' lies *c.* 164 kcal. above the ^3P ground-state). Accordingly, although we recognize the power of the argument of Long and Norrish regarding the assessment of L_1, we are unable to accept it as conclusive, and are generally of the opinion that further direct experimental work, probably on the dissociation of CO or CN or on the later stages of the stepwise dissociation of CH_4, is necessary to settle this important problem.

Note added in proof.—In connexion with the final sentence of our note, we would direct attention to the new direct measurement of L_1 by Brewer, Gilles and Jenkins[9] referred to by Pitzer[10]. They obtain the value $170{\cdot}39 \pm 0{\cdot}20$ kcal. for L_1 at 0° K.

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[4] Bichowsky and Rossini, "Thermochemistry of Chemical Substances" (New York, 1936).
[5] Lewis and Randall, "Thermodynamics" (New York, 1923).
[6] Long and Norrish, (*a*) *Nature*, **157**, 486 (1946); (*b*) *Proc. Roy. Soc.*, A, **187**, 337 (1946); (*c*) *Nature*, **158**, 237 (1946).
[7] Shenstone, *Phys. Rev.*, **72**, 415 (1947).
[8] Van Vleck, *J. Chem. Phys.*, **2**, 20, 297 (1934).
[9] Collected Abstracts of papers read at the 113th Meeting of the American Chemical Society, April, 1948.
[10] *J. Amer. Chem. Soc.*, **70**, 2140 (1948).

I am very grateful to the courtesy of the authors of the foregoing letter and the Editors of *Nature* for the opportunity of appending a reply to the criticisms involved.

In the previous paper with Prof. Norrish[1], the remark that Pauling's listed values of bond-energies contain values which are deficient for links involving carbon is consistent with the fact that Pauling, in his section on the energies of covalent bonds[2], describes the covalent bond by a wave function in which the coefficients of the various ψ values are such that make the bond-energy a maximum. Having thus introduced the concept of bond-energy, Pauling, in comparing thermochemical bond-energies, naturally makes no attempt to divorce their meaning from the wave-mechanical representation, which, on the contrary, would seem to be required by the above definition of Skinner and Springall in the case of compounds of tetravalent carbon. In this connexion, it has frequently been pointed out[3] that the carbon atoms must have the sp^3 configuration to provide the appropriate wave functions. Accordingly, the low values of the carbon bond-energies calculated thermochemically from the ground s^2p^2 state are deficient according to Pauling's *usage*, since they bear to the required values no closer relation than the fivepence change bears to the cost of a seven-penny article for which a shilling has been paid. The two usages are not, in our opinion, based on different definitions, the example quoted by Pauling by way of definition being identical with our manner of definition.

It is true that the same principle must be applied to a large number of bonds other than those involving carbon. Cases in point are the boron trihalides, which require the unpairing of the *s* electrons on the boron atom and its promotion to the sp^2 configuration. For co-ordinate links to oxygen, on the other hand, as in the amine oxides and oxyacids of chlorine, for example, the question is one of pairing the two unpaired electrons on the oxygen atom, that is, bringing it from a triplet to a singlet state. None of the examples quoted by Skinner and Springall involving varying degrees of bond polarity create any more difficulty to the one point of view than to the other so far as covalent links are concerned, and it is difficult to see their relevance to the discussion. For heteropolar molecules such as Na^+Cl^-, the bond-energy is not to be confused with the ionic attraction, which is related to the dissociation energy by an algebraic function of the ionization energy of the metal atom and the electron affinity of the non-metal atom. In cases such as the BeH molecule, the relevant atomic states required to give a stable molecular orbital are not normally in doubt, even though the dissociation scheme may involve the avoidance of crossed potential energy curves. It is the contention of this note that an application of the principles of electron-pairing to the selection of atomic terms for the derivation of bond-energies does not in itself lead to ambiguity, and that failure to apply these principles has on occasions led to erroneous conclusions, as pointed out previously[1,4].

It is not a fair statement of the facts to say that we assumed the bonds in CH_3 and CH_4 to be roughly equivalent in strength, since these strengths are interrelated with L_2, for which limits were derived in our paper. It likewise follows from these limits that the reorganisation energy of CH_3 on its formation from CH_4 is small. It may need to be pointed out here that, according to the initial definition we gave[1] for the bond-energy E, the energy of reorganisation calculated from experimental data is a *net* effect which includes the effects due to any possible change in the bonding to sp^3 and repulsion between the hydrogen atoms (as well as all other secondary effects within the molecule such as that due to delocalization of the bonding electrons[3]), so that the remarks of Skinner and Springall concerning these factors are beside the point and do not apply here. The same conclusions also follow from the original definition of energy of reorganisation[5]:

$$\text{energy of linkage} = \text{energy of dissociation} + \text{energy of reorganisation}.$$

It is, of course, possible to define bond-energies in such a way that all these effects are separated out, but we adopted the more usual convention of including them.

The remaining point concerning the 'valence-state' of carbon as calculated by Van Vleck[6] is also one of convention. Adopting Van Vleck's convention, it is necessary for the sake of consistency to calculate bond-energies from the 'valence-states' of all other atoms (which in the case of oxygen and nitrogen, for example, are *not* the ^3P and ^4S states respectively), the energies of some of these states having also been calculated[7]. On this basis, the criticism put forward by Skinner and Springall conflicts with their own definitions laid down at the outset of their communication. Again, we adopted the usual convention of referring bond-energies to atomic states. The identification of the tetravalent state of carbon with the ^5S level seemed at the time, in the absence of a spectroscopic value, to be confirmed by the calcu-

lations of Ufford[8] and experimental data concerning the CN radical[1]. The discrepancy with the recent observations of Shenstone[9] will be dealt with in a future communication. It is in no sense responsible for the discrepancy between our conclusions and those of Springall[10] concerning the heat of atomization of carbon, this being due to entirely different reasons which are discussed in a forthcoming paper.

In conclusion, it seems to me that the expression 'mean bond-energy term' is an unfortunate choice. As originally employed for polyatomic molecules by Butler and Polanyi[11], a constancy in energy is assumed for any one kind of link from molecule to molecule, differences in the dissociation energies being attributed entirely to resonance energy of the resulting radicals. This point of view ignores changes in the energy of unruptured links during a dissociation process, whereas the statement that bond-energies according to Skinner and Springall's usage (*a*) show "a remarkable degree of constancy" seems difficult to maintain in the face of much experimental evidence. If this were so, then every process of the type

$$CH_4 + CO_2 \rightarrow 2H_2CO,$$

in which the number of each type of bond remains the same, would be thermoneutral, whereas this is far from being the case. The example quoted is endothermic to the extent of about 60 kcal., which must be attributed to changes in the energies of the C—H or C=O bonds or, more probably, both. The extent to which the bond-energies (as distinct from the dissociation energies) of C—H, C=O and many other bonds do, in fact, vary has received frequent consideration in the literature[12].

L. H. Long

University College,
Exeter.

[1] Long, L. H., and Norrish, R. G. W., *Proc. Roy. Soc.*, A, **187**, 337 (1946).
[2] Pauling, L., "The Nature of the Chemical Bond", 47 ff. (Cornell Univ. Press, New York. 2nd Ed., 1945).
[3] See, for example, Coulson, C. A., *Quart. Rev. Chem. Soc.*, **1**, 144 (1947).
[4] Long, L. H., and Norrish, R. G. W., *Nature*, **15**', 486 (1946).
[5] See the discussion to the paper by Norrish, R. G. W., *Trans. Farad. Soc.*, **30**, 103 (1934).
[6] Van Vleck, J. H., *J. Chem. Phys.*, **2**, 20, 297 (1934).
[7] Mulliken, R. S., *J. Chem. Phys.*, **2**, 782 (1934).
[8] Ufford, C. W., *Phys. Rev.*, ii, **53**, 568 (1938).
[9] Shenstone, A. G., *Phys. Rev.*, ii, **72**, 411 (1947).
[10] Springall, H. D., *Trans. Farad. Soc.*, **43**, 177 (1947).
[11] Butler, E. T., and Polanyi, M., *Trans. Farad. Soc.*, **39**, 19 (1943).
[12] See, for example, the discussions and references given by Walsh, A. D., *Trans. Farad. Soc.*, **43**, 60 (1947); *J. Chem. Soc.*, 398 (1948).

GERMAN MOTOR ROADS

BEFORE the War much interest was taken in Great Britain in the German *Autobahnen*. Their design and construction were well described then in both the technical and popular press. The system is the only modern road network planned on a national scale and is worthy of most careful study in order that practice in Britain and elsewhere may profit as much as possible from German experience. The recent B.I.O.S. Overall Report*, entitled "German Motor Roads, 1946", is therefore particularly valuable in that it gives comprehensive information on the present state of these roads. The report, which contains thirty-nine excellent plates, is clearly and succinctly written and can be strongly recommended to the general reader.

* British Intelligence Objectives Sub-committee Overall Report No. 5. (H.M. Stationery Office, 1948.) 1*s.* 6*d.* net.

The roads have been laid out on new ground, independently of existing roads, so as to link the main cities and industrial areas. The great extent of the system is emphasized by the fact that although a length of some 2,380 miles of dual-carriageway road is already in service, only about one half of the length originally planned has been completed. One of the chief impressions gained by the observers was of the high quality maintained throughout rather than of any exceptional excellence in particular sections, which were nowhere better than has been achieved elsewhere. This consistency is attributed to the policy of working to a single standard determined centrally, and of employing contractors carefully selected for their ability to undertake work of such a magnitude. The designs of the later roads were modified in the light of the experience gained from those already in service.

An admirable feature is the absence of extensive cracking of the concrete surfaces; this has been achieved by building on a gravel foundation, the material being imported if it was not already available locally. The elaborate plans adopted at crossings and road junctions to avoid the conflict of traffic lanes are well known; when adequately signposted, these are not found to be confusing. Another striking feature is the design of bridges; a great variety of construction has been used to suit local conditions and the workmanship is described as being of outstanding merit. Fifteen photographs in the report give a good idea of the lightness of effect achieved in over-bridges and of the pleasing design of the under-bridges; the latter carry the roads across valleys and are often larger than are met with in common practice owing to the stringent gradient restrictions which were maintained. Care has also been taken to blend the roads into the landscape by careful location, by rounding the slopes of cuttings and embankments, and by the method of planting adopted.

The report finally concludes that "the lay-out and alignment of the German motor roads are of a sufficiently high standard to suggest a degree of safety and sense of security above that obtained on ordinary main roads in Britain". Undoubtedly we can learn much not only from the felicities of this great experiment but also from its defects, a number of which are recorded and illustrated. R. H. Macmillan

CONSTITUTION OF THE PLANETS

MORE than thirty pages of the first part for this year of the Monthly Notices of the Royal Astronomical Society are devoted to "Reports on the Progress of Astronomy", under which is included "The Constitution of the Planets", "Solar Activity", "Comets" and "Double Stars". By far the longest of these is the first, and it is possible to glance at only a few of the points dealt with by Rupert Wildt.

Quite recently our view that satellites could not retain atmospheres has been shown to be incorrect, as methane absorption has been discovered in the spectrum of Titan. The atmosphere of Titan, which is stable under present conditions, would have its stability endangered if its temperature were raised by only 100° C. Hence, if the evolution of the satellite passed through a stage of high surface temperature—as is believed to have happened with all the members of the solar system—the atmosphere

of Titan must have been formed subsequent to that period. Kuiper believes that the same argument applies, with almost equal force, to Mars and perhaps to Venus and the earth also. He points out that the existence of methane on Titan suggests a genetic relation to its primary or to the other giant planets, and shows that the satellite cannot be the product of capture from an elliptical orbit extending into the interior region of the solar system.

At the end of the review it is pointed out that there are four different groups of phenomena which are worthy of some attention as possible clues to the history of the solar system. These are: (1) The correlation between the mass of a planet and the size and composition of its atmosphere-oxides on the terrestrial planets and hydrides on the giant planets. (2) The existence in Saturn's system of two types of satellites with densities greater than that of rock and less than that of water. (3) The nature and origin of the envelopes of low density characteristic of all the giant planets. The theory of Kuhn and Rittmann rules out the possibility of gravitational separation leading to the formation of a heavy core and more especially in the giant planets; and if their view should be accepted, the marked concentration of density towards the centre of the giant planets would favour the accretion theory of planetary formation. (4) The mean chemical composition of the planets in relation to the composition of the sun. As it is possible to explain the scarcity of light elements on the terrestrial planets by dissipation, no further cosmogonic inferences can be made so far as this is concerned. Of course, if the planetary matrix were much richer in lighter elements than the bulk of the sun, some doubts would be thrown on the formation of the planets by sudden ejection from the sun, which would have been accomplished by an unavoidable loss of hydrogen. When more accurate values for the mean composition of the sun and giant planets are available, they may facilitate a choice between the rival theories of the origin of the solar system, through a sudden catastrophe with subsequent rapid condensation, or through gradual accretion.

OSLER AS A SCIENTIST*

By Sir ARTHUR MacNALTY, K.C.B.

SIR WILLIAM OSLER is famous for many things. He was a great physician of two continents, a scholar, a humanist, a teacher and a medical administrator. His work as a scientist has perhaps received less recognition, yet it is revealed on every page of his famous text-book of medicine. As Harvey Cushing wrote[1]: "The volume, indeed, was what might be called a practical pathology in which were given the results of modern investigation, microscopical, bacteriological, and chemical. On this foundation was built up the symptomatology and diagnosis of disease. . . ." His school-master, the Rev. W. A. Johnson, at Weston, near Toronto, introduced him to the study of biology, geology and the use of the microscope. At eighteen years of age, Osler began to tabulate and study his collection of the Diatomaceæ; and his interest in biology was stimulated further, when he entered the Toronto Medical School in 1868, by Dr. James Bovell. "I am at Dr. Bovell's every Saturday and we put up preparations for the microscope," he writes.

* A paper read to the Osler Club on July 12.

His first publication was a short sketch entitled "Christmas and the Microscope" (*Hardwicke's Science-Gossip*, London, Feb. 1, 1869), in which he describes the diatoms and Infusoria he identified in a bottle of water. In 1870 he presented to the Natural History Society of Montreal the results of his studies on the Diatomaceæ of Canada, enumerating 109 species under twenty-nine genera and describing the structure, mode of division and propagation of the diatom[2]. In 1877 he read a paper before this Society on Canadian fresh-water Polyzoa[3] and published a supplementary note on this paper in the *Canadian Naturalist*, 1881[4]. He mentioned a species of *Cristatella* as having been found in abundance and described a new species of *Pectinatella*.

In 1872–73 Osler had spent fifteen months in the Physiology Laboratory, University College, London, working at physiology and histology under Prof. Burdon-Sanderson. While there he was offered the chair of botany in McGill University; but declined it as insufficiently qualified for the post. At University College he began working "On the Action of certain Reagents—Atropia, Physostigma and Curare—on the Colourless Blood-Corpuscles"[5]. The published results were negative. In 1873 he made his most important contribution to scientific knowledge by investigating with Edward Schäfer the form and movement of the blood platelets. Though a few previous workers, for example, Bizzozero and Hayem, had observed these bodies, "the third element of the blood", it was Osler who saw them first in the circulating blood and carefully described them, and his observations were presented before the Royal Society by Burdon-Sanderson in 1874[6]. Afterwards, he published several papers and lectures on the blood, including one on the development of blood corpuscles in the bone-marrow[7]. All this work established Osler's reputation as an original investigator.

Returning to Montreal in 1874 as lecturer of Institutes of Medicine, he studied the 'entozoa', and R. Ramsay Wright, professor of biology at Toronto, named a trematode worm, which Osler had found in the gills of a newt, *Sphryanura Osleri*[8]. Osler, as professor of physiology in the Veterinary College, Montreal, and vice-president of the Montreal Veterinary Medical Association, also worked at comparative pathology, being one of the first to realize its importance in relation to medicine. He published several papers on this subject during the next few years. In the first of them, on a form of bronchopneumonia in dogs, he described a previously unknown parasitic nematode as the causal agent[9]. This organism was afterwards renamed *Filaria Osleri* by Cobbold in 1879. The most important of the other papers dealt with hog cholera[10], echinococcus[11], cestode tuberculosis[12] and the parasites in the Montreal pork supply[13]. As a by-product of this latter investigation he took up the subject of trichinosis and echinococcus infections in man. He studied the parasites in the blood of the frog, demonstrating and classifying *Rana mugiens*, the *Trypanosoma Sanguinis* (Grubby) and the *Drepanidium ranarum* (Lankester)[14].

Osler confirmed Koch's discovery of the tubercle bacillus as the cause of tuberculosis in 1882; but he never became an adept in bacteriological technique. Harvey Cushing, his biographer, considered that at first he inclined towards Bastian's belief in spontaneous generation, and by the time that Pasteur's views had been accepted, he had abandoned experimental medicine and comparative pathology for the clinical study of disease. The call to Philadelphia to be

professor of clinical medicine in the University of Pennsylvania in 1884 marks the end of Osler's investigations as a pure scientist in the fields of zoology and physiology. In these fields he had achieved reputation as a trained microscopist and had made important contributions to knowledge. As W. T. Councilman said: "He could easily have become a great scientist, but he chose the path which led to the formation of the great clinician which he became; a worthy associate of the great men who have made English medicine famous"[18].

Already at Montreal Osler had used the microscope in his pathological studies and continued to promote pathological research in association with clinical investigation in the Philadelphia and Baltimore periods. Thus his Goulstonian Lectures on malignant endocarditis[16], based entirely on autopsies performed in Montreal, contained the first comprehensive account in English of the disease and are largely clinical and pathological, but not experimental. He suggested that malignant endocarditis was invariably of bacterial origin; he stained the organisms in the tissues and made a few inconclusive inoculation experiments; but left to others the task of bacteriological investigation of this malady.

One of Osler's last pieces of microscopical investigation was his confirmation in 1886 of Laveran's discovery of the malarial parasite[17]. It was due to Osler's prompt appreciation of this discovery that the prevalent theory of a mysterious nocturnal 'miasma' was overthrown in the United States, and in his Baltimore Clinic, a few years later, he insisted that no diagnosis of malaria should be made without a microscopic examination of the blood. His hæmatological studies led him to take a special interest in diseases of the blood, and he described in 1902 "cyanosis with polycythæmia"[18], since known as 'Osler's disease'. A hereditary malady characterized by multiple telangiectases associated with hæmorrhages[19] is also styled 'Osler's disease'.

Throughout his professional life, William Osler applied his scientific knowledge to the study of clinical disease and brought the laboratory to the bedside. His teaching in this respect has greatly influenced the progress of clinical medicine. He referred to this guiding star of his work in the following words: "To the physician particularly a scientific discipline is an incalculable gift which leavens his whole life, giving exactness to habits of thought and tempering the mind with that judicious faculty of distrust which can alone, amid the uncertainties of practice, make him wise unto salvation"[20].

[1] Cushing, H., "The Life of Sir William Osler", **1**, 359 (Oxford, 1925)
[2] *Canad. Naturalist and Quart. J. Sci.*, 1870–71, N.S., **5**, 142 (Montreal)
[3] *ibid.*, N.S., **10**, 399 (1883).
[4] *ibid.*, N.S., **11**, 473 (1881).
[5] *Quart. J. Mic. Sci., Lond.*, N.S., **13**, 307 (1873).
[6] *Proc. Roy. Soc.*, **22**, 391 (1873–74).
[7] *Trans. Assoc. Adv. Sci.*, Salem, Mass., **31**, 512 (1883).
[8] Wright, R. R., "Contributions to American Helminthology", *Proc. Canad. Inst.*, N.S., **1**, No. 1 (1879).
[9] "Verminous Bronchitis in Dogs", *Veterinarian, Lond.*, **1**, 387 (1877).
[10] "On the Pathology of the So-called Pig Typhoid", *Vet. J. and Ann. Comp. Path., Lond.*, **6**, 385 (1878).
[11] *Trans. Path. Soc., Phila.*, **13**, 222 (1885–87).
[12] *Amer. Vet. Rev., N.Y.*, **6**, 6 (1882).
[13] *Canada Med. and Sci. J., Montreal*, **11**, 325 (1882–83).
[14] *Canad. Naturalist, Montreal*, N.S., **10**, 406 (1883).
[15] *Johns Hopkins Hosp. Bull.*, **30**, 197 (1919).
[16] *Brit. Med. J.*, **1**, 467, 522, 577 (1885).
[17] *Trans. Path. Soc., Phila.*, **13**, 255 (1885–87) and *Brit. Med. J.*, **1**, 556 (1887).
[18] *Amer. J. Med. Sci., Phila.*, N.S., **126**, 187 (1903).
[19] *Johns Hopkins Hosp. Bull.*, **12**, 333 (1901).
[20] "The Leaven of Science", *Univ. Med. Mag., Phila.*, **6**, 573 (1893–94), and in "Æquanimitas" (London, 1904).

SCIENCE OF THE AMARYLLIDS

THE American Plant Life Society, organised for the increase and diffusion of knowledge concerning plant-life, issues the year-book "Herbertia", which is devoted to the Amaryllids. Issues for 1946 and 1947 appeared together late in 1947 (from the Society, Box 2398, Stanford, California), and contain some useful papers of scientific interest. A detailed account of "the karyo-systematics of the sub-genus *Ajax* of the genus *Narcissus*" (Vol. 13, 1946) is contributed by A. Fernandes and Rosette Fernandes of Portugal. Of about eighteen species, fourteen are diploids, normally with $n = 7$. *Narcissus hispanicus* is constituted of diploid and triploid forms, *N. tortuosus* is triploid, and *N. bicolor* tetraploid. Fifteen somatic chromosomes are found in *N. asturiensis*, *N. minor*, *N. pumilus* and *N. pallidiflorus*. Since all the species have the same karyotype, this supports the idea of Baker (1888) that the group is a single, very polymorphic Linnean species. The different forms have arisen by gene mutation and polyploidy.

A useful description of narcissus disease symptoms and control is given by Charles J. Gould (Vol. 13, 1946), with several photographs. Perhaps the most interesting to British readers is a virus disease rather appropriately named 'decline', but also known as 'white streak'. A corresponding paper on insect and mite pests of narcissus by E. P. Breakey mentions the narcissus bulb fly, the lesser bulb fly and bulb mites, all of which are already known in Great Britain. It is usual to grow Amaryllids for their garden beauty, but M. J. Cox and M. M. MacMasters show (Vol. 14, 1947) that starch can also be prepared from the tuberous roots of *Alstræmeria aurantiaca* and *A. chilensis*. Granules from the former are simple, but those from the latter have an unusual compound nature. Both give pastes which have similar characteristics to other root starches.

There are also shorter articles on all aspects of Amaryllid culture, breeding and classification.

JOHN INNES HORTICULTURAL INSTITUTION

FOR thirty-eight years, the John Innes Horticultural Institution has been carrying out detailed investigations in plant culture, genetics, breeding and other matters. 'J.I.' composts are now widely used and have perhaps done more than anything else to make the name of the Institution familiar to gardeners. The annual report for 1947, recently issued, gives the results of many continued researches. M. B. Crane has obtained a certain amount of resistance to pear scab, *Venturia pirina*, from crosses between the pear varieties Giffard and Conference. Rogues in tomatoes are shown by D. Lewis to appear most frequently when the plants are grown at high temperatures (26° C.). The same author has analysed seven X-ray induced mutations of the incompatibility gene of *Œnothera*. They do not confer complete self-compatibility; but the work is being continued. K. Mather has investigated the three types of gene which affect heterostyly in *Primula sinensis*. The difference of morphology and physiology between pin-eyed and thrum-eyed flowers is determined by the major genotype, and finally adjusted by the polygenotype. Miss A. Vines has studied breeding system and genetic isolation in *Antirrhinum*, and A. J. Bateman has

estimated the effect of various isolation systems on contamination in seed production.

Work on plant improvement by crossing has been carried out for uniform coloration of fruit in tomato (G. M. Haskell) and for combining the dwarf habit of *Phaseolus vulgaris* with the extended inflorescence of *P. multiflorus* (L. G. Wigan).

The Cytology Department, under Dr. C. D. Darlington, director of the Institution, has worked on the effect of cell gradients in controlling the development of nuclei in the pollen grain. The occurrence of dwarf pollen has engaged the attention of L. F. la Cour, who discusses the relative merits of segregation and differentiation as a cause. Further studies include the effect of X-rays on meiosis, and chromosome breakage by temperature shock. An interesting development in the Garden Department, under W. J. C. Lawrence, is the effect of artificial lighting on the yield of tomato plants. Daylight fluorescent tubes lit for 6 hr. a night for the first twenty nights after germination resulted in a much heavier yield of fruit, particularly in the first three weeks of picking.

The Institution is still carrying out its long-term programme of removal to Bayfordbury, Hertford; but it is expected to be some time before the transfer is complete.

APPOINTMENTS VACANT

APPLICATIONS are invited for the following appointments on or before the dates mentioned:

RESEARCH OFFICER AT THE DIVISION OF INDUSTRIAL CHEMISTRY, Melbourne—The Chief Scientific Liaison Officer, Australian Scientific Research Liaison Office, Africa House, Kingsway, London, W.C.2, quoting No. 1765 (September 4).

HEAD (male) OF THE POULTRY DEPARTMENT at the Ulster Dairy School (for girls), Cookstown, Co. Tyrone—The Establishment Officer, Ministry of Agriculture, Stormont, Belfast (September 4).

LECTURER IN AGRICULTURE AND FARM BOOKKEEPING, and a LECTURER IN AGRICULTURE, FARM IMPLEMENTS, BUILDING CONSTRUCTION, etc., at the Cheshire School of Agriculture, Reaseheath—The Director of Education, County Education Offices, City Road, Chester (September 4).

INSTRUCTRESSES (2) IN DAIRYING AND POULTRY-KEEPING—The Secretary, Edinburgh and East of Scotland College of Agriculture, 13 George Square, Edinburgh 8 (September 4).

CHEMIST, and a PHYSICIST—The Secretary, Hosiery Research Council, 4 First Avenue, Sherwood Rise, Nottingham (September 4).

RESEARCH PHYSICO-CHEMIST at the Research Institute of the Foot-and-Mouth Disease Research Committee—The Director, Research Institute, Pirbright, Surrey (September 4).

DEMONSTRATOR IN CHEMISTRY AND BIOCHEMISTRY with a special interest in Physical Chemistry—The Dean of the Medical College, St. Bartholomew's Hospital, West Smithfield, London, E.C.1 (September 4).

LECTURER IN THE ENGINEERING AND MINING DEPARTMENTS to take Electrical Technology and Mechanical Engineering with mining qualifications—The Registrar, University College, Cathays Park, Cardiff (September 4).

LECTURER IN ENTOMOLOGY, an AGRICULTURAL ECONOMIST, and an ASSISTANT AGRICULTURAL ECONOMIST—The Registrar, The University, Bristol 8 (September 4).

LECTURER or ASSISTANT LECTURER IN PHYSICS—The Principal, College of Technology, Manchester (September 6).

BIOLOGIST (Technical Officer) as HEAD OF THE BIOLOGICAL SECTION of the Technical and Scientific Register—The Ministry of Labour and National Service, Appointments Department, Technical and Scientific Register (K), York House, Kingsway, London, W.C.2, quoting G.351/48A (September 6).

MECHANICAL ENGINEER (Ref. C.528/48A), and a STANDARDS AND CO-ORDINATION ENGINEER (Ref. C.529/48A), at the Atomic Energy Research Establishment, Harwell—The Ministry of Labour and National Service, Technical and Scientific Register (K), York House, Kingsway, London, W.C.2, quoting the appropriate Ref. No. (September 6).

AGRICULTURAL ECONOMIST (male)—The Registrar, Wye College, Wye, Ashford, Kent (September 7).

J. G. GRAVES MEDICAL RESEARCH FELLOWSHIP for full-time research in some branch of medical science approved by the Faculty of Medicine—The Registrar, The University, Sheffield 10 (September 11).

ASSISTANT IN THE ENGINEERING DEPARTMENT, London H.Q.—The Director, Personnel Department, British Council, 3 Hanover Street, London, W.1 (September 11).

EDITORIAL ASSISTANT (with degree in physical science with bias towards physics and mathematics) to the Royal Society—The Ministry of Labour and National Service, Technical and Scientific Register (K), York House, Kingsway, London, W.C.2, quoting A.270/48A (September 11).

LECTURER IN ANTHROPOLOGY with special reference to India—The Secretary, School of Oriental and African Studies, University of London, London, W.C.1 (September 11).

SENIOR LECTURER IN MATHEMATICS at the New England University College, Armidale, New South Wales—The Secretary, Universities Bureau of the British Empire, 32 Woburn Square, London, W.C.1 (September 15).

ASSISTANT BACTERIOLOGIST (with an Honours Science Degree in Bacteriology), and an ASSISTANT BIOCHEMIST (with an Honours Degree in Science and special experience in Biochemistry), to the Northern Regional Hospital Board—The Secretary and Administrative Medical Officer, Ralgmore Hospital, Inverness (September 15).

PROFESSOR OF BOTANY at Fouad I University, Cairo—The Director, Egyptian Education Bureau, 4 Chesterfield Gardens, London, W.1 (September 15).

ASSISTANT LECTURERS (2) IN THE DEPARTMENT OF CIVIL ENGINEERING—The Professor of Civil Engineering, Queen's University, Belfast (September 15).

RESEARCH OFFICER IN THE BUILDING RESEARCH SECTION, Melbourne—The Chief Scientific Liaison Officer, Australian Scientific Research Liaison Office, Africa House, Kingsway, London, W.C.2, quoting No. 1547 (September 18).

ASSISTANT LECTURER or LECTURER IN AGRICULTURAL ECONOMICS—The Registrar, The University, Leeds 2 (September 22).

EXPERIMENTAL OFFICERS and ASSISTANT EXPERIMENTAL OFFICERS AT THE DEPARTMENT OF ATOMIC ENERGY, Springfields, Lancs, to carry out experimental work arising from the metallurgical development involved in the production of atomic energy—The Ministry of Labour and National Service, Technical and Scientific Register (K), York House, Kingsway, London, W.C.2, quoting F.391/48A (September 25).

PRINCIPAL RESEARCH OFFICER IN THE MICROBIOLOGICAL DIVISION of the National Chemical Research Laboratory, Pretoria—The South African Scientific Liaison Officer, Africa House, Kingsway, London, W.C.2 (September 30).

FISHERIES ASSISTANT AND NATURALIST (temporary) for research at the Marine Biological Station, Port Erin—The Registrar, The University, Liverpool (September 30).

CHAIR OF MECHANICAL ENGINEERING—The Registrar, The University, Leeds 2 (September 30).

UNIVERSITY LECTURER, preferably with special qualifications in Fluid Dynamics, Atomic Physics or Algebra—The Secretary of the Appointments Committee, Trinity College, Cambridge (September 30).

READERSHIP IN METALLURGY in the Department of Coal, Gas and Fuel Industries—The Registrar, The University, Leeds (September 30).

KENNEDY CHAIR OF MECHANICAL ENGINEERING at University College—The Academic Registrar, University of London, Senate House, London, W.C.1 (October 7).

DIRECTOR OF RESEARCH at the Hosiery Research Council's Research Station at Thorneywood House, Nottingham—The Director, National Hosiery Manufacturers' Federation, 104 Regent Road, Leicester (October 15).

CHAIR OF GEOLOGY at King's College—The Academic Registrar, University of London, Senate House, London, W.C.1 (October 25).

PROFESSOR OF CIVIL ENGINEERING, and a PROFESSOR OF ELECTRICAL ENGINEERING, at the Thomason College of Engineering (Roorkee University)—The High Commissioner for India, General Department, India House, Aldwych, London, W.C.2, quoting No. 412A (October 30).

CHAIR OF ZOOLOGY at King's College—The Academic Registrar, University of London, Senate House, London, W.C.1 (November 1).

FISHERIES OFFICERS in Malaya—The Director of Recruitment (Colonial Service), Sanctuary Buildings, Great Smith Street, London, S.W.1.

TSETSE FLY RANGER by the Government of Nyasaland, for tsetse fly survey and reclamation duties—The Crown Agents for the Colonies, 4 Millbank, London, S.W.1, quoting M.N.21794/3F.

SCIENTISTS (*a*) with research and practical experience in Coal Mining, Coal Preparation and Carbonization and Briquetting (Ref. TT/70), and (*b*) to take charge of the Chemistry Laboratories and with all-round research experience with specialist knowledge in Coal Chemistry, Analytical work, Metallurgy or Coal Tar (Ref. TT/71)—The National Coal Board, Establishments (General) Branch, Hobart House, Grosvenor Place, London, S.W.1, quoting appropriate Ref. No.

SUPERINTENDENT OF THE SCOTTISH LABORATORIES, involving responsibility for all chemical, mechanical and micrographic testing, and for advisory service to Scottish members—The Secretary, British Cast Iron Research Association, Alvechurch, Birmingham.

GEOLOGISTS for research on concentration of iron ore (*a*) with special knowledge of petrology or sedimentary rocks, (*b*) with experience of ore dressing problems—The Personnel Officer, British Iron and Steel Research Association, 11 Park Lane, London, W.1.

RESEARCH ASSISTANT IN STATISTICS (preferably with Degree in Mathematics)—The Lecturer in the Design and Analysis of Scientific Experiment, 91 Banbury Road, Oxford.

SENIOR ENGINEER IN THE LAND DRAINAGE BRANCH of the Public Works Department, Sierra Leone—The Director of Recruitment (Colonial Service), Colonial Office, Sanctuary Buildings, Great Smith Street, London, S.W.1.

LECTURER IN RADIO ENGINEERING—The Clerk, Northern Polytechnic, Holloway, London, N.7.

VISITING DEMONSTRATOR IN THE DEPARTMENT OF BACTERIOLOGY—The Secretary, King's College of Household and Social Science, Campden Hill Road, London, W.8.

REPORTS and other PUBLICATIONS

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Catalogue

Technique: a Journal of Instrument Engineering. Vol. 2, No. 2, April. Pp. 9–16. Transmission Measuring Set, Type D-514-A. (Bulletin B.610.A.) Pp. 2. (Beckenham: Muirhead and Co., Ltd., 1948.)